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EDITED BY

J. ALLEN HOWE, B.Sc., F.G.S.

(Authors alone are responsible for the opinions and facts stated in their respective Papers.)

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Page 57, line 22, *for* "Boium" *read* "Bojum."
„ 69, line 24, *for* "Bojums" *read* "Bojum."
„ 99, line 46, *for* "W. H. Whitaker" *read* "W. Whitaker."
„ 141, last line, *for* "earth and ore" *read* "earth lore."
„ 154, lines 32 and 35, *for* "Green Sand" *read* "Greensand."
„ 157, line 33, *for* "Green Sand" *read* "Greensand."
„ 158, line 8, *for* "Green Sand" *read* "Greensand."
„ 161, line 13, *for* "Chalk" *read* "Coast."
„ 169, line 35, *for* "situated" *read* "saturated."
„ 174, line 16, *for* "*reticulatus*" *read* "*reticulatum*."
„ 189, line 21, *for* "marked" *read* "worked."
„ 204, line 37, *for* "XXI and XXII" *read* "XXII and XXIII."
„ 205, line 12, *for* "XX and XXI" *read* "XXI and XXIII."
„ 206, line 19, *delete* (Pl. XXXVIII).
„ 207, line 23, *for* "Sandwick" *read* "Sanwick."
„ 225, line 21, *for* "acres" *read* "areas."
„ 464, line 37, *for* "Bed" *read* "Beds."
„ 468, line 30, *for* "Reitot" *read* "Rutot."
Pl. XXVII *for* "Thorwick" *read* "Thornwick."
„ XLI *for* "Johnson" *read* "Johnston."

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This Paper comprises:—(1.) A detailed **Description of the Beds**, the result of several years' careful study of the Parisian Tertiaries and close communication with many eminent French geologists. (2.) A practical **Guide for the Field-Geologist** to all the best exposures, based on personal experience. (3.) A **Revised List of the Mollusca**, showing their range in time, with **Lists of other Fossils**.

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PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

VOL. XVIII.

THE ZONES OF THE WHITE CHALK OF THE ENGLISH COAST.

By Dr. ARTHUR W. ROWE, F.G.S.

III.—DEVON.

THE CLIFF-SECTIONS BY C. DAVIES SHERBORN.

[PLATES I. TO XIII.]

(Read March 7th, 1902.)

THE WHITE CHALK OF THE DEVON COAST.

FROM PINHAY CLIFF TO BERRY CLIFF.

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INTRODUCTION.

IF the Chalk exposures of the neighbouring coast of Dorset afford views of greater variety and grandeur, and the physical features are more complex and remarkable, those of Devonshire, on the other hand, are almost equally full of contrast and fascination, and possess a beauty which is all their own. The Dorset coast may be called the land of the great fault; that of Devonshire the country of the landslip. The great landslip alone would stamp any coast with a distinctive individuality, and the contrast afforded by the juxtaposition of red Triassic marl, yellow Greensand, and White Chalk, realise a field of rare geological interest, and a picture of surpassing beauty.

Though we have here but a limited zonal range, extending from the zone of *Rhynchonella cuvieri* to that of *Micraster cor-testudinarium*, the fauna of the two lower beds is so rich that we are amply recompensed for a restriction in field-work, which would otherwise be somewhat disappointing. This coast affords a scope for the study of Echinoderma which alone would render any section famous. Moreover, the accessibility of the cliffs, and the unaltered state of the chalk, make these disconnected exposures a veritable paradise for the collector.

On p. 75 of his great work,* Dr. Barrois states that we have a capping of the zone of *Micraster cor-anguinum* at Hooken Cliff and Rousden, and that possibly a thin layer of *Marsupites*-zone may be found at the latter situation. We have carefully examined every available exposure, and have no hesitation in saying that there is no zoological evidence whatsoever for the existence of these two zones on the Devonshire coast. That higher beds have existed, and have been removed by denudation, is obvious from the fact that we find flint casts in the surface gravels of *Micraster*, and more rarely of *Echinocorys*, of the shape-variations

* Recherches sur le Terrain Crétacé Supérieur, 1876.

typical of the *Micraster cor-anguinum*-zone. We have also evidence of a still higher horizon, hitherto unsuspected, in the presence of a flint cast of a well-preserved *Marsupites* plate, found by Mr. F. G Collins, of Exeter, on White Cliff fall. Through the courtesy of Mr. Collins we now have this unique specimen in our collection.*

The section which we describe extends from Pinhay Cliff on the east to Berry Cliff on the west, and there is hardly a point which is not readily accessible at ordinary low tides. In addition, many isolated exposures are situated in the landslip and on the cliff top, so that they can be worked when the tide is unfavourable for the examination of the coast-line.

Seaton is situated in the middle of the section, and being served by the railway is the natural headquarters for the district. Excellent accommodation is readily obtained here; but for those who wish to study the landslip alone, perhaps Lyme Regis would be more convenient. At present neither Lyme Regis nor Beer is connected with the railway.

PINHAY CLIFFS.

The whole of the landslip is private property, and permission to examine the Clevelands section, in which Pinhay Cliff is situated, should be obtained from Mr. Wilton Allhusen, of Clevelands, and for the Rousden Cliffs from Lady Peek, of Rousden. We have found both these landowners most courteous in affording facilities for working the cliffs. A toll of sixpence is levied by the tenants of Dowlands Farm for the privilege of using their private road from the farm to the landslip, and this gives one the right to examine the Dowlands Cliffs.

The landslip is best examined in the early spring or late autumn, when the trees are devoid of leaf, as the vegetation is so luxuriant that the inland cliffs are completely hidden by it. Those who choose the early spring will be amply repaid by the wealth of wild flowers with which the landslip is literally carpeted. Leathern gaiters are indispensable, alike for the brambles, which are here quite tropical in their luxuriance, and for the adders, which are not uncommon.

The fine inland cliff of Pinhay stands back 220 yards from the coast, crowning the undercliff levels, and has an altitude of 400 feet above sea level. It is magnificently air-weathered, and save for the tangle of vegetation at the base, easily worked. It is fairly rich in fossils, and worth visiting if only for the fact that it affords the solitary accessible junction on this coast between the zones of *Terebratulina gracilis* and *Holaster planus*, and between *Holaster planus* and *Micraster cor-testudinarium*.

* Confirmatory evidence on this head has lately been furnished by Mr. Jukes Browne in a contribution entitled, "*Marsupites* in the Flints of the Haldon Hills," *Geol. Mag.* Oct., 1902, p. 449.

Clevelands is about six miles by road from Seaton, and five miles on foot across the country. Those who choose to reach the landslip by leaving the beaten track can take the footpath along the top of Haven Cliff, and dip down into the Bindon landslip, and so pass eastwards through the Dowlands, Rousden, Charton, and Whitlands divisions of the landslip to Pinhay; or they can take the main road to Dowlands Farm, and pass through the private road to the Dowlands cliffs. We prefer to cross the golf-links, pass up Long Close Lane to Dowlands, through Rousden and Charton, and the take then footpath past Whitlands to Clevelands. Passing through the lodge gates we inquire for the path which leads to the Chapel Rock. As we near the Chapel Rock we pass a small exposure, on the north side of the path, in the zone of *Micraster cor-testudinarium*, situated above the letter *R* in Rock Orchard (6-inch map, Devon, lxxxiv, N.E., and S.E.). From this we obtained *Micraster præcursor* of the group-form characteristic of this zone, *Echinocorys gibbus*, and *Nautilus* cf. *atlas*. The presence of *Nautilus* in this zone is sufficiently rare to warrant a record, and we are indebted to Mr. Crick for the determination of this species.

Still working to the west we pass another small section on the north side of the path, above the capital letter *O* in Rock Orchard. From this we collected *Micraster præcursor* of the group-form characteristic of the *Holaster planus*-zone, *Micraster leskei*, *Micraster cor-bovis*, *Holaster planus*, *Pentacrinus*, *Terebratula carnea*, and *Rhynchonella reedensis*. There can be no doubt, therefore, that this exposure is in the zone of *Holaster planus*.

A few paces more bring us to the main section, with the Chapel Rock to the south of it. A glance at the latter shows that it is merely a slipped face from the main cliff, for all the lithological features are common to both. We especially note a very strong orange-coloured band of nodular chalk at the top both of the cliff and the Chapel Rock.

Pinhay Cliff Main Section.

Standing on the footpath on the north side of the Chapel Rock we face the main section of Pinhay Cliff. It is splendidly weathered, and the nodular chalk stands out in rugged bosses from the surface. The Chapel Rock is so close to the main cliff that it is impossible to take a photograph of it without tilting the camera to such an extent as to throw the whole picture out of focus. This is particularly unfortunate, as it is the only good exposure showing the junctions of the zones of *Terebratulina gracilis* and *Holaster planus*, and *Holaster planus* and *Micraster cor-testudinarium*.

We have tried to obtain local information concerning the

date of the detachment of the Chapel Rock from the main cliff, but have failed to secure authentic data. Miss Helen Allhusen says, "we have no record about the Chapel Rocks beyond the belief that they were formed before the 16th Century, as tradition says that they were used as a place for secret worship during the religious persecutions in the reigns of Mary and James."

By climbing up the talus on the east and west sides of the main cliff we are able to work every foot of the *Holaster planus*-zone, and to establish an accurate zoological junction with the zones immediately above and below it. Nowhere else on this coast are we able to examine an exposure of this zone which is accessible in its entire extent.

We notice that there is a thin marl-seam at the point where the talus joins the cliff at the middle of the main section, and at the bottom of the trench, which separates the main cliff from the Chapel Rock, we see a small exposure. We work this exposure and find in it an abundance of *Terebratulina gracilis*, *Holaster planus*, and several examples of *Micraster cor-bovis*, but no other forms of *Micraster*. We are clearly here in the zone of *Terebratulina gracilis*. Extending our search above the marl-band we at once find a greater abundance of *Holaster planus*, and numerous examples of *Micraster leskei* and of *Micraster præcursor* of the group-form associated with the *Holaster planus*-zone, while *Terebratulina gracilis* becomes notably rarer. It is evident, therefore, that the marl-band is the actual zoological junction of the zones of *Terebratulina gracilis* and *Holaster planus*. We shall see later that this marl-band is a constant feature throughout the coast, and that it always forms the line of division between these two zones.

Ascending the talus on the east side of the main cliff we find an abundant and characteristic fauna of the *Holaster planus*-zone as far as a strong nodular flint-line, which occurs 26½ ft. above the basal marl-seam. We still ascend the talus, and find the same fauna for another 13 ft., when we meet with a thin, but well-defined, tabular band of flint. Between the strong flint-line and the thin tabular flint-band we note a scattered line of *Echinocorys vulgaris* var. *gibbus*. Above the thin tabular flint-band the essential features of the test of *Micraster* change; *Micraster cor-bovis*, *Micraster leskei*, and *Holaster planus* die out, and are replaced by *Micraster præcursor* of the group-form associated with the zone of *Micraster cor-testudinarium*. This thin tabular flint-band is, therefore, the dividing line between the zones of *Holaster planus* and *Micraster cor-testudinarium*, and is an almost constant feature throughout the coast. It is not present, however, at Annis' Knob (Beer Harbour), nor could we trace to our satisfaction the two strong flint-lines, 1½ ft. apart, which are well seen at the base of the same bluff.

Still ascending the talus we examine the cliff wherever it is

accessible, and find, even at the top, no evidence of a fauna suggestive of the *Micraster cor-anguinum*-zone. The whole of the upper part of the cliff is, therefore, clearly in the zone of *Micraster cor-testudinarium.*

Taking the lithological features of the *Micraster cor-testudinarium*-zone in detail we note a marl-band 4 ft. above the thin tabular flint-band, and a second one 4 ft. above the first. Higher up still we see two strong yellow bands of nodular chalk, above that a very thin double tabular flint-band, and close to the top the strongest band of yellow nodular chalk that we have ever seen. It is almost orange in colour. This is the strong yellow band which is seen at the top of the Chapel Rock.

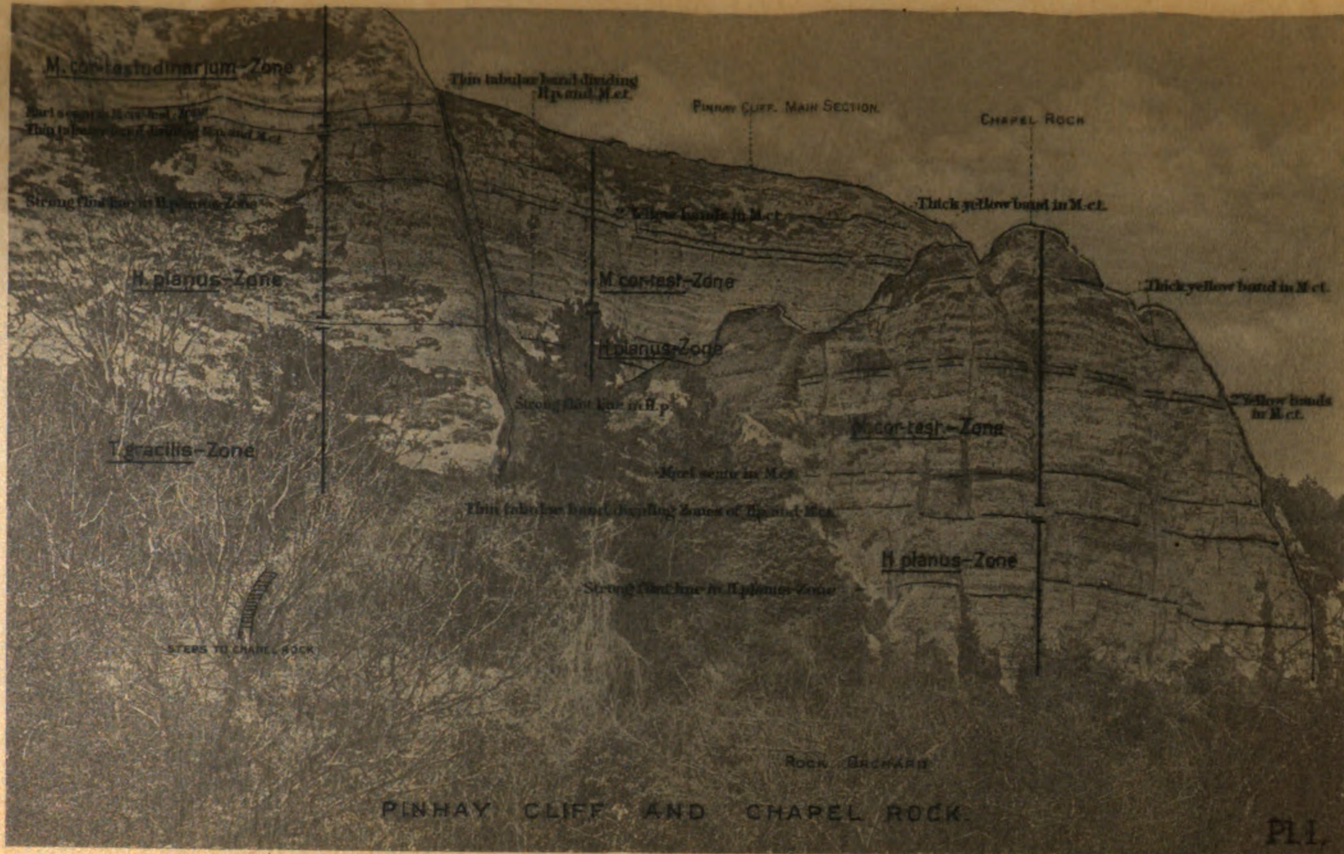
South of the main cliff, and to the east of the Chapel Rock, is another slipped face of chalk, and this is also in the zone of *Micraster cor-testudinarium*, and yields a characteristic fauna. We climbed the northern face of the Chapel Rock, and obtained two fine examples of *Micraster præcursor*, just under the topmost yellow nodular band. We especially note these urchins because they absolutely disprove the existence of even a cap of the zone of *Micraster cor-anguinum.*

Only a portion of the zone of *Micraster cor-testudinarium* is exposed, but we should estimate that a thickness of 45 to 50 ft. is shown here. Nowhere on this coast is the zone in question fully exposed, so that we have no means of estimating its original thickness. The three yellow nodular bands are indicated on Pl. I as well as the chief marl-seam, but we could not put in all the other features in the main cliff, as the Chapel Rock stands in the way. The photograph is taken from the main path in the landslip, south of the Rock Orchard. The marl-seams are worthy of mention, as they are rare features in this zone; but we record a similar instance in the Beachy Head section (*Proc. Geol. Assoc.* xvi (6), 1900, Part I, Kent and Sussex, p. 327).

We have given the details of the main cliff at length, because we have no other fairly complete section which is accessible, and for the reason that we shall refer to them in other exposures of the zones of *Holaster planus* and *Micraster cor-testudinarium* in the western portion of the coast. We summarise them as follows for the *Holaster planus*-zone:

From the strong nodular flint-line to the thin tabular flint-band	13 ft.
From the marl-seam, at the junction of the talus with the centre of the main cliff, to the strong nodular flint-line...	26½ ft.
Total thickness of *Holaster planus*-zone ...	39½ ft.

Still following the path on the north side of the Chapel Rock to the westward we notice a projecting mass of cliff, facing south and east, which joins the main section at right angles. It is from



PINHAY CLIFF MAIN SECTION, AND CHAPEL ROCK.

accessible and find, even at the top, [illegible] *Micraster coranguinum*-zone. [illegible] upper part of the cliff is, therefore, clearly in the [illegible] *cor-testudinarium*.

Taking the lithological features of the *cor-testudinarium*-zone in detail we note a marl-band [illegible] tabular flint-band, and a second one [illegible] Higher up still we see two strong yellow bands [illegible] above that a very thin double tabular flint-band [illegible] top the strongest band of yellow nodular [illegible] seen. It is almost orange in colour [illegible] band which is seen at the top of the [illegible]

South of the main cliff, and to the [illegible] another slipped face of chalk, and [illegible] *Micraster cor-testudinarium*, and [illegible] climbed the northern face of the [illegible] fine examples of *Micraster* [illegible] yellow nodular band. We [illegible] they absolutely disprove the [illegible] *Micraster coranguinum*.

Only a portion of the zone of [illegible] exposed, but we should estimate that a [illegible] shown here. Nowhere on this coast is [illegible] exposed, so that we have no means of [illegible] thickness. The three yellow nodular bands [illegible] as well as the chief marl-seam, but [illegible] other features in the main cliff, as [illegible] way. The photograph is taken from [illegible] slip, south of the Rock Orchard. [illegible] mention, as they are rare features [illegible] similar instance in the Beachy [illegible] xvi (6), 1900, Part I, Kent and Sussex [illegible]

We have given the details of the [illegible] we have no other fairly complete section [illegible] for the reason that we shall refer to the [illegible] zones of *Holaster planus* and *Micraster* [illegible] western portion of the coast. We submit [illegible] the *Holaster planus*-zone:

F[illegible] strong nodular flint-line [illegible] ... ...

F[illegible] marl-seam, at [illegible] of the main [illegible] to the [illegible] ... ...

Total thickness [illegible] *Holaster planus*-[illegible]

[illegible] following the path on the north side of [illegible] westward we notice a projecting mass of [illegible] which joins the main section at right [illegible]

BINHAY CLIFF MAIN SECTION, AND CHAPEL ROCK.

this recess that the Chapel Rock has been torn. We examine the surface which faces eastward, and find a splendidly weathered exposure of *Terebratulina gracilis*-zone, from which we obtained numerous examples of *Holaster planus*, *Micraster cor-bovis*, and also saw a fine specimen of *Ammonites peramplus*. By climbing up the talus we were able to check the measurements of the *Holaster planus*-zone, and found that they exactly coincide with those obtained on the talus at the eastern side of the main cliff. We noted that the upper limit of the *Terebratulina gracilis*-zone is formed here, as on the eastern side, by a well-marked marl-seam, and that from this point to the steps we have this zone exposed for a thickness of 37 ft.

The upper beds of the *Terebratulina gracilis*-zone are very nodular, and the flint-lines are far apart. From an ordinary inspection one would have no hesitation in assigning them to the zone of the *Holaster planus*, but by carefully collecting below the limiting marl-seam we find only *Holaster planus*, *Micraster cor-bovis*, and an abundance of *Terebratulina gracilis*, and no evidence of *Micraster præcursor* or *Micraster leskei*. We call attention to the deceptive naked-eye appearance of this chalk, because we shall find the knowledge which we have here obtained of much service in the Hooken and other western sections which are not so readily accessible.

Descending to the main path of the landslip, on the south of the Rock Orchard, we note that immediately to the east of the Chapel Rock is a finely weathered exposure. It is very nodular, but the flint-lines in the lower portion are widely separated, as in the western mass of the main cliff, and the upper beds much more closely seamed with flint. About 3 ft. from the base is a thin marl-seam, and below this *Terebratulina gracilis* is abundant, and *Micraster cor-bovis* occurs, while above it *Micraster præcursor* and *Micraster leskei* are found. Here again we have the actual junction of the zones of *Terebratulina gracilis* and *Holaster planus*. This section does not appear in Pl. I, and we were unable to obtain a photograph of it on account of the thickness of the vegetation.

We now examine the southern face of the Chapel Rock in detail. This mass has been somewhat disjointed in its slide forwards, as indicated in Pl. I, and the base is much obscured by tangled vegetation; but by dint of climbing, and forcing one's way through the bushes, the whole of it can be worked.

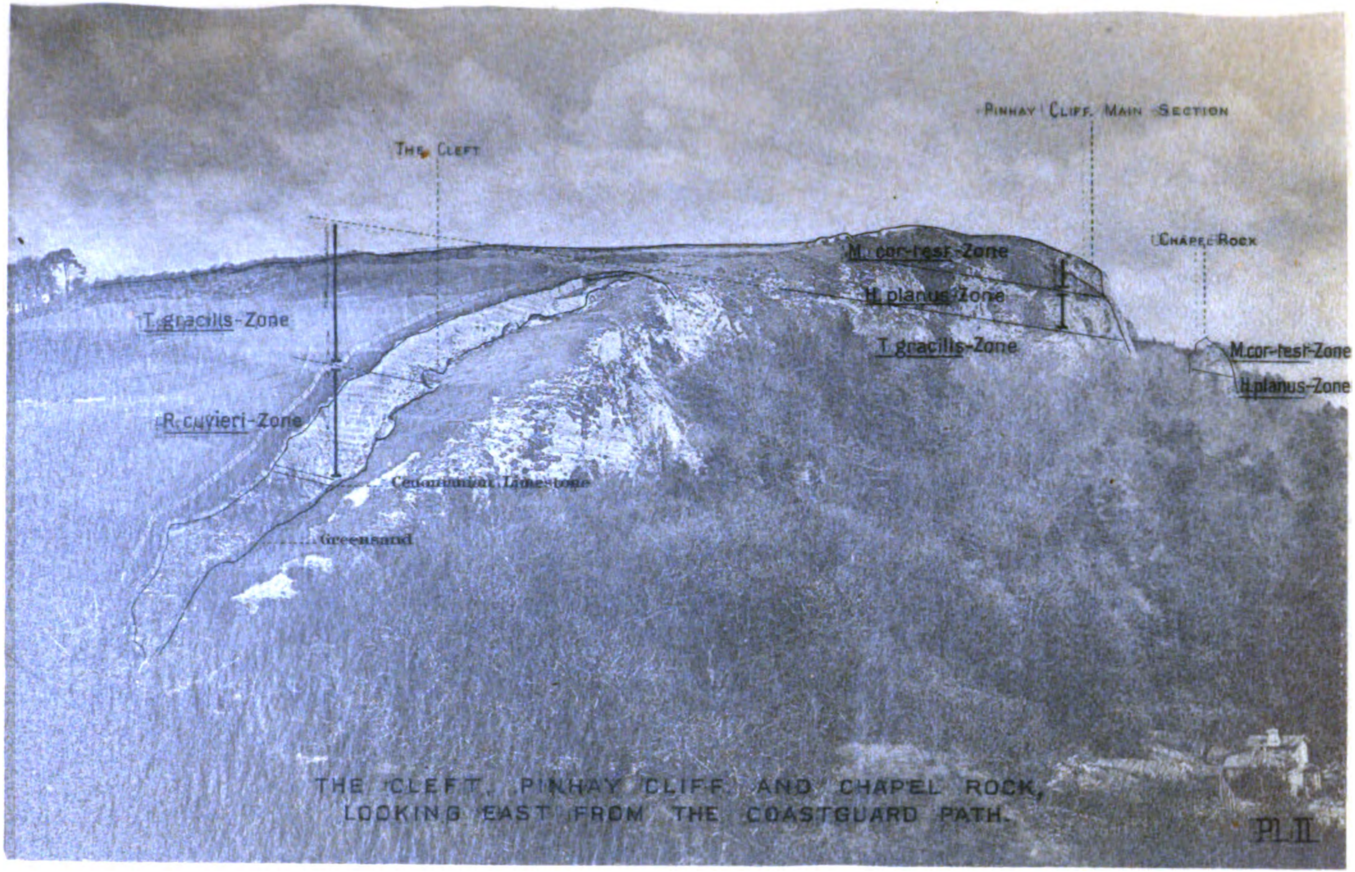
We begin on the east side, and climb up the talus, so as to get over the shoulder of the Chapel Rock on to the path on its northern aspect. On our way up we pass the strong nodular flint-line in the *Holaster planus*-zone, then the thin tabular flint-band dividing this zone from that of *Micraster cor-testudinarium* and finally the marl-bands and yellow bands of nodular chalk noted in the main section on p. 5. The zoological evidence

exactly coincides with that obtained in working the main cliff, and the same band of *Echinocorys* was found, as before noted.

Returning to the base of the Chapel Rock we find that there is no portion of the *Terebratulina gracilis*-zone exposed. If any exists, it must be covered by the earth. At the base of the mass we see two fairly strong flint-lines 16 ft. below the very strong nodular flint-line (not 15 ft., as at Annis' Knob), and these may be the same pair which we shall note in the latter situation, but failed to distinguish in the main cliff. Working to the west we see a crack in the bluff by which we can climb nearly to the top, and we are thus able to completely check the zoological data obtained by climbing the talus on the east side of the Chapel Rock. We collected a fine series of *Micraster* from the whole of the southern face of the Chapel Rock at its base, and they, together with the other fossils, were completely illustrative of the fauna of the *Holaster planus*-zone.

Neither here nor in the main cliff could we establish the presence of a true Chalk Rock. The surface is a mass of extremely hard, iron-stained nodular bands, and there are not a few phosphatic and glauconitic nodules scattered throughout the zone, but there are no bands which we could safely assign to this peculiar bed. We found two examples of *Turbo gemmatus*, and one of *Pleurotomaria perspectiva*, but this record hardly constitutes a zoological Chalk Rock.

The remainder of Pinhay Cliff to the west is too obscured by grass and vegetation to be worth examining in detail, so we pass westward along the broad main track to the Great Cleft, north of West Cliff Cottage. Here we see a repetition of the process by which the Chapel Rock was detached (Plate II). The Cleft began to form in the year 1886. Miss Allhusen says, "It has been gradually widening for the past ten years. In 1892 it was only a small fissure, and for the succeeding three years one could jump across it. Lately, however, it has widened much more rapidly." One can traverse this deep Cleft from bottom to top, and so obtain a measurement of the zones. We find that the base of the Cleft is cut in Greensand, capped by Cenomanian Limestone (zone of *Ammonites mantelli*), and then we come to the *Rhynchonella cuvieri*-zone. This chalk is very dirty, but we obtain a characteristic fauna from it as far as the first flint-line. This gives us a measurement of $59\frac{1}{2}$ ft. for the *Rhynchonella cuvieri*-zone. Here, as elsewhere on this coast, with the exception of Berry Cliff, we take the base of the *Terebratulina gracilis*-zone from the lowest flint-line, as we find that above it the chalk invariably loses its nodular character, and *Terebratulina gracilis* is found in abundance. The whole of the remainder of the gap is cut in a whiter and softer chalk, with frequent flint-lines and marl-bands, measuring n all $71\frac{1}{2}$ ft. The fauna is abundant, and fully characteristic of the *Terebratulina gracilis*-zone, and especially



THE GREAT CLEFT AT PINHAY CLIFF, FROM THE WEST.

in the upper part, where the weathering is more complete, examples of the name-fossil are found in profusion, many of them being of unusual size. There is no evidence of an *Holaster planus*-zone fauna, even at the top of the Cleft, so it is clear that we have only an incomplete section of the *Terebratulina gracilis*-zone, though, as is shown in Pl. II, we must be very close to the top of the zone. At the highest point the chalk is still soft and white, and we see no sign of the nodular chalk, which is characteristic of the upper beds of this zone, as described on p. 7. In the Cleft we were unable to find the two pairs of yellow nodular chalk bands above the first flint-line in the *Terebratulina gracilis*-zone, though there are two yellow bands about 20 ft. higher up. Whether they are the same two pairs of yellow bands which we describe in the White Cliff section (p. 13) is impossible to say. So far as the white chalk is concerned, the measurements for the Great Cleft work out as follows :—

Terebratulina gracilis-zone (as exposed)	71½ ft.
Rhynchonella cuvieri-zone	59½ ft.

On leaving the Great Cleft it is important that we should closely follow the narrow coastguard track, which is always marked by white stones, as the whole landslip is a veritable labyrinth of small paths, which cross each other at every angle, and appear to lead to nowhere in particular. The coastguard track leads straight to Whitlands. As soon as we reach the rising ground, after passing over the swamp below the Cleft, we notice a large block of Greensand which has been blazed with whitewash by the coastguard. From this point of vantage we look back on the Cleft and Pinhay Cliff, and can thus obtain a graphic idea of the whole exposure, and the dip and relative position of the various zones. This idea of relative position and perspective is entirely lost when we examine the beds at close range, for the vegetation is so luxuriant that we can only see the portion of the cliff actually in front of us. The photograph of Plate II was taken from the top of a Greensand hillock a little N.W. of the blazed block of Greensand.

WHITLANDS.

This section is worthy of examination, as it is the only one on the east of Seaton where the *Rhynchonella cuvieri*-zone is clean and weathered, that in the Cleft being too dusty to study with any degree of satisfaction. There is a coastguard path up the cliff, and by branching off from this good collecting may be obtained by climbing the grassy slopes. The contrast between the *Rhynchonella cuvieri*-chalk on the east and west of this coast is very marked, apart from the mere question of thickness. Here we have thick beds of comparatively smooth and soft chalk

seamed by bands intensely hard and nodular. In the west, on the other hand, the beds are so compacted that the whole zone is made up almost exclusively of nodular bands, frequently deeply ironstained. It will be seen, however, that at Berry Cliff, west of Branscombe, the chalk of this zone is somewhat similar in its general appearance to that of the Whitlands section, with the notable exception that it is much softer and seamed with flint-lines. The extreme base of the *Rhynchonella cuvieri*-zone here is glauconitic and quartzose, and the fossils therein show an affinity with the Cenomanian rather than the true fauna of this zone. These evidences of local contemporaneous erosion are common along this coast. The same feature is shown in some of the fallen masses in the Hooken, especially in one on the north-west side of the northern pinnacle. This section at Whitlands yielded us a rather scanty but typical fauna of the *Rhynchonella cuvieri*-zone for about 55 ft., up to the first flint-line; but above that level the chalk is softer, seamed with flint-lines, and *Terebratulina gracilis* is abundant. The latter zone is exposed for about 30 ft.

Rhynchonella cuvieri-zone	about 55 ft.
Terebratulina gracilis-zone (as exposed) . .	about 30 ft.

Charton Cliffs.

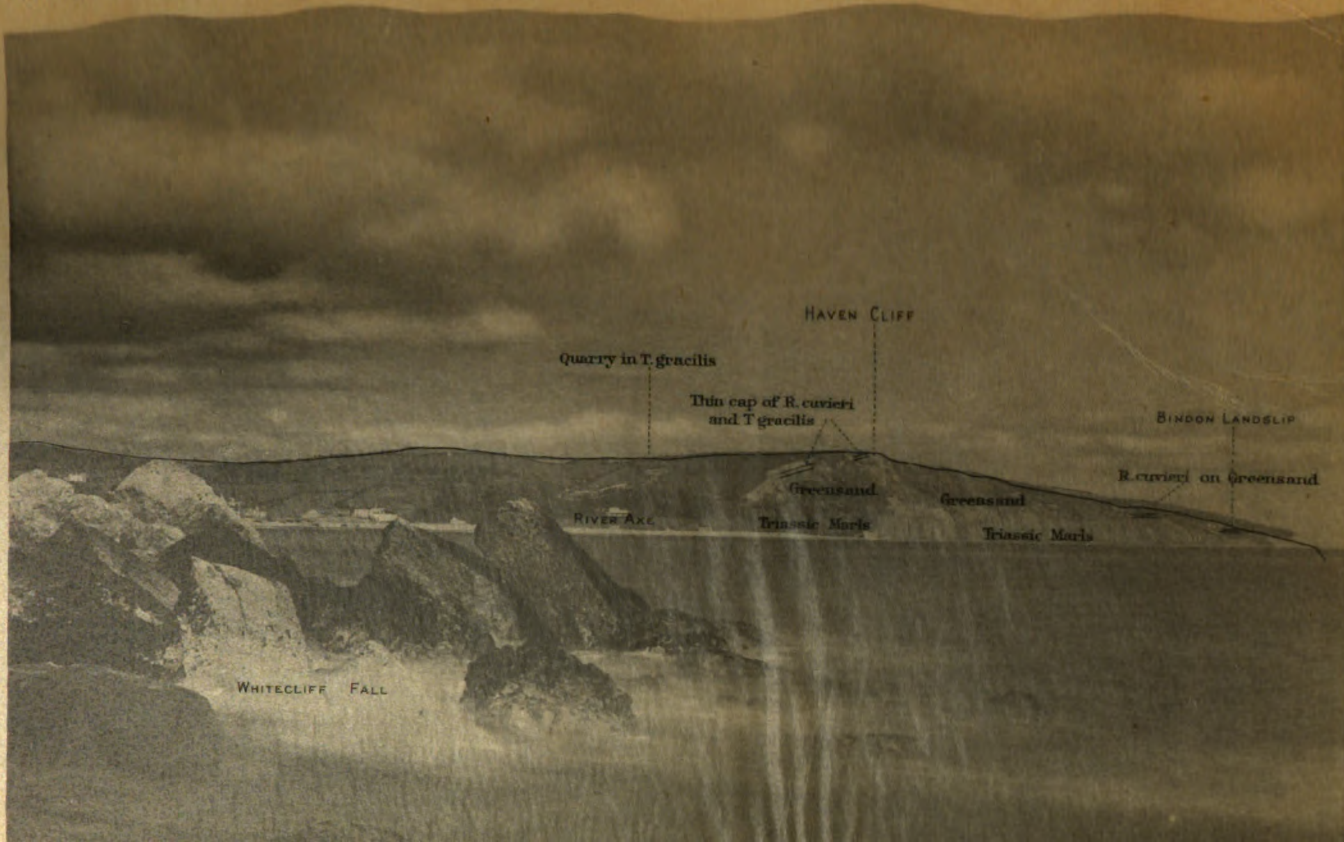
The Charton division of the landslip gives no good section for collecting or measurement, and consists chiefly of *Rhynchonella cuvieri*-zone resting directly on the Upper Greensand, with no Cenomanian Limestone intervening. The *Rhynchonella cuvieri*-zone, where capable of being worked, yields the ordinary fauna, though fossils are not easily found, owing to the dusty nature of the surface.

Rousden Cliffs.

These cliffs are not worth working, as the chalk is out of reach. There is a capping of the zone of *Terebratulina gracilis* on that of *Rhynchonella cuvieri*.

Dowlands Cliffs.

The Dowlands portion of the landslip is much more accessible, and consists of the zones of *Rhynchonella cuvieri* and *Terebratulina gracilis* resting on Greensand. There are a few well-weathered sections which may be reached by arduous climbing, but those in the *Rhynchonella cuvieri*-zone are disappointingly unfossiliferous, and the bulk of the exposures, both in the zone and that above it, are too obscured by rainwash to afford good results. At the western entrance to the Dowlands landslip the *Terebratulina gracilis*-zone is well exposed and accessible, and it can also be reached on the top of the cliff on the south side of


Haven Cliff
Quarry in T. gracilis
Thin cap of R. cuvieri
and T gracilis
Bindon Landslip
R. cuvieri on Greensand
Greensand
Greensand
River Axe
Triassic Marls
Triassic Marls
Whitecliff Fall

the rift, where it is useless from the collector's point of view. The only well-weathered surfaces in either zone are in the large slipped faces which front the sea, and these yielded a considerable and characteristic fauna of both zones.

It may be mentioned that throughout the whole length of the landslip, from east of Pinhay to Dowlands, many isolated fallen blocks from the zones of *Rhynchonella cuvieri* and *Terebratulina gracilis* are found on the shore, and these are often fairly fossiliferous. At Humble Point, south of Pinhay Cliff, we find fine masses from both zones, as well as Cenomanian Limestone, but the blocks from the *Rhynchonella cuvieri*-zone were disappointingly poor in fossils.

Haven Cliff.

Here we have a splendid cliff of red Triassic Marl, overlain by Greensand, and capped by White Chalk at its western end. It is impossible to get measurements of this chalk, but the beds exposed are chiefly those of *Rhynchonella cuvieri*, with here and there a thin layer of the extreme base of the *Terebratulina gracilis*-zone. The *Rhynchonella cuvieri*-zone is much thinner than at Pinhay and Whitlands, and more approaches the measurement obtained at White Cliff.

North of Haven Cliff is an old quarry on the golf-links, which contains the remains of a lime-kiln. The chalk is white and soft, and shows a flint-line and marl-band. It is badly weathered and much broken-up, but we obtained from it *Inoceramus mytiloides*, *Rhynchonella cuvieri*, *Discoidea dixoni*, *Holaster planus*, *Terebratula semiglobosa*, and *Bourgueticrinus ellipticus*. It is clear that we have here a section in the base of the zone of *Terebratulina gracilis*, though the name-fossil was not discoverable.

Plate III shows Haven Cliff, on the east side of Seaton, and indicates the position of the Triassic Marls, the Greensand, and the thin capping of white chalk. North of this is seen the situation of the old quarry in the *Terebratulina gracilis*-zone, and in the distance, towards the east, the Bindon landslip is shown with the thin capping of White Chalk on the Greensand.

White Cliff to Beer Harbour.

From Seaton to Seaton Hole we pass along low cliffs of red Triassic Marl, and at the latter point cross over the line of the fault which brings the Greensand to the shore-line. At low tide this line can readily be traced on the reefs. The fine headland called White Cliff is now in front of us, based in Greensand and crowned with White Chalk (Plate IV). Below the highest and most eastern point of White Cliff is a steep turf-clad talus, strewn with fallen blocks, chiefly from the zone of *Terebratulina gracilis*,

and fringed towards the sea by still larger blocks, mainly from the same zone and that of *Rhynchonella cuvieri*. This fine fall can be examined at any state of the tide, only the outer fringe of rocks being covered at high water and overgrown with seaweed

The walk from this point to Beer Harbour under the cliffs is by no means an easy one, as the foreshore is a tumble of slippery fallen blocks; but the distance is only one-third of a mile. Beer Harbour can be reached through the cave at East Ebb at any ordinary low tide, but occasionally the tide does not fall low enough to enable one to do so. At the east side of Connett's Hole a ledge of Greensand runs out, which also bars one's progress until the tide has fallen (Plate V).

Unquestionably the best view of these fine cliffs is to be obtained by standing on the rocks, at extreme low tide, south of the Scar at East Ebb. From this point we can take in a view from the northern end of White Cliff to Arratt's Hill, which crowns the western limb of Beer Harbour, and it was from this situation that the photograph which forms Plate VI was obtained. As in all raking views, the camera flattens and foreshortens the picture in a disappointing manner, and without the aid of a key-plate it would be impossible to bring out the salient angles of the cliff.*

From White Cliff to Beer Harbour the beds dip sharply to form the northern slope of the Beer syncline. So sharp is the fall that the Greensand, which occupies more than half the lofty face of White Cliff, is reduced to about 10 ft. at King's Hole; so that from Connett's Hole to King's Hole the cliffs are cut almost entirely in White Chalk, ranging from the zone of *Rhynchonella cuvieri* to that of *Holaster planus*. On the western side of Beer Harbour the beds are horizontal, the base of the cliff being cut in Greensand ledges along the whole arm of the bay. When we round the corner below Arratt's Hill the coast runs in a westerly direction, and the true dip of the beds is seen falling towards Beer, and forming the other limb of the Beer syncline. We now proceed to take the section in detail.

WHITE CLIFF TO KING'S HOLE (EAST EBB).

The term White Cliff is apparently used on the 6-inch Ordnance Survey Map to cover the section from Seaton Hole to King's Hole (East Ebb), but locally it is applied to the highest and most northern portion of the cliff, and we shall, therefore, use the term in its local and restricted sense. By climbing up the steep talus under White Cliff we can readily examine the junction of the White Chalk with the Cenomanian Limestone, and obtain a measurement of the zone of *Rhynchonella cuvieri*.

* Plates V and VI are from negatives taken under our direction by Mr. E. Good, photographer, The Square, Seaton.

White Cliff to East Ebb, from Seaton Beach.

Zone of Rhynchonella cuvieri.

From the top of the Cenomanian Limestone, which overlies the Greensand, to the first flint-line in the soft white chalk of the *Terebratulina gracilis*-zone is $28\frac{1}{2}$ ft. Between these two levels we have an intensely hard, nodular, and iron-stained chalk devoid of flints, and fairly rich in all the characteristic fossils of this zone. Better collecting, however, will be obtained from the fallen blocks on the talus than from the cliff itself. This chalk in its lithological appearance conforms closely to all the other sections in this zone with which we are acquainted.

Rhynchonella cuvieri-zone = $28\frac{1}{2}$ ft.

Zone of Terebratulina gracilis.

The contrast between the *Terebratulina gracilis*-chalk and that of the zone below attracts the eye at once. Instead of the rugged, flintless, and discoloured chalk of the *Rhynchonella cuvieri*-zone, we have a soft, white, marl-veined chalk, crowded with flint-lines, with two notable bands of marly chalk in which are no flints. In the lower part of the *Terebratulina gracilis*-zone are three features which are fairly constant along this coast, and we allude to them in detail, as they are useful in the Hooken, where the lower beds disappear. They are also helpful in working the blocks on White Cliff fall, for we can sometimes assign, by their assistance, fossils to their proper level in this zone. We refer to two pairs of yellow nodular chalk-bands, and to the 2-foot and 4-foot bands of marly and flintless chalk. The lower pair of yellow nodular bands measures 2 ft., and the higher $1\frac{1}{2}$ ft. The 2-foot band of marly flintless chalk is based by a strong flint-line, and below the 4-foot band of marly flintless chalk are two strong nodular flint-courses, 3 ft. 6 in. apart. These three strong flint-courses are notable features in the northern side of Beer Harbour, and can be readily traced with the naked eye even from Arratt's Hill. As we shall have to compare the measurements from the Cenomanian Limestone to the base of the 2-foot band of marly flintless chalk at White Cliff and the Hooken, we give them in detail for the former section.

From the top of the higher pair of yellow nodular bands to the base of the 2-foot band of marly flintless chalk ...	20 ft.
From the base of the lower pair of yellow nodular bands to the top of the higher pair of yellow nodular bands ...	11 ft.
From the first flint-line in *Terebratulina gracilis*-zone to the base of the lower pair of yellow nodular bands	4 ft.
From the Cenomanian Limestone to the first flint-line in the *Terebratulina gracilis*-zone (i.e. the thickness of *R. cuvieri*-zone)	$28\frac{1}{2}$ ft.
	$63\frac{1}{2}$ ft.

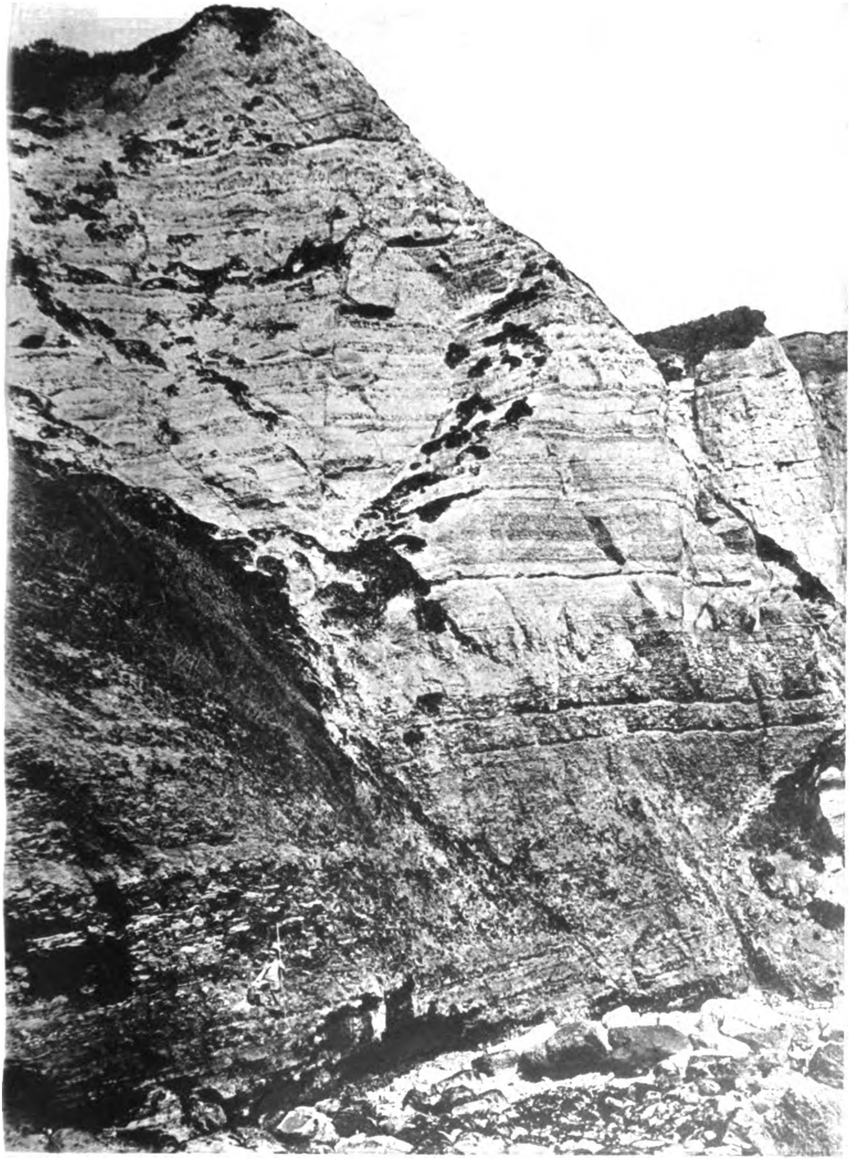
It will be seen, therefore, that the distance from the base of the *Rhynchonella cuvieri*-zone to the base of the 2-foot band of marly flintless chalk is $63\frac{1}{2}$ ft.

The remainder of the *Terebratulina gracilis*-zone is difficult to measure, as the talus is steep, and there are no further features to note save the presence of the 4-foot marly flintless band higher up in the cliff. Both these bands are indicated on Plate V, which is not a view of White Cliff, but of a beautifully weathered bluff immediately to the west of Connett's Hole. We should judge that at White Cliff there is another 35 ft. above the 2-foot marly flintless band, which would give a total exposure of the *Terebratulina gracilis*-zone at this point of about 70 ft. On the same plate is seen the boundary between this zone and that of *Holaster planus*, which caps the cliff from White Cliff to Beer Harbour. The lithological line of division is formed by a thin marl-band, which generally weathers out as an open seam. This marl-band is constant throughout the coast, being especially well shown at Pinhay (Pl. I) where it enables one to obtain a definite junction between the zones of *Terebratulina gracilis* and *Holaster planus*. A reference to this is made on pp. 5-7, and it is well indicated on Pl. VI. It is worthy of note that in this instance the lithological and zoological boundary lines coincide with absolute accuracy.

Zone of Holaster planus.

Above the marl-band in question the chalk is greyer in colour, and markedly nodular. The mere naked-eye appearance would at once suggest that we were entering another zone, and an examination of this bed at Annis' Knob proves that the horizon is that of the *Holaster planus*-zone. Curiously enough there are no fallen blocks which can be assigned to this zone between White Cliff and East Ebb, a circumstance which is due to the fact that all the fallen blocks at this point are covered with seaweed. The reason that we find none from this zone on White Cliff fall is that this chalk is there merely a layer at the summit of the cliff.

It is quite clear that we have no exposure of the *Micraster cor-testudinarium*-zone between White Cliff and Annis' Knob, for until we reach the latter section we do not see the strong flint-line 13 ft. below the zoological junction between this zone and that of *Holaster planus*, nor can we detect the pair of flint-lines, $1\frac{1}{2}$ ft. apart, which are situated at the base of Annis' Knob, 15 ft. below the flint-course just mentioned. We have, therefore, no complete exposure of the *Holaster planus*-zone between White Cliff and East Ebb, though in the cliff face between the White Cliff fall and the small fall west of Connett's Hole we cannot have less than 40 to 50 ft. of greyish, rugged, and nodular chalk shown. If this estimate be correct we have a



SECTION AT CONNETT'S HOLE.

greater thickness of the *Holaster planus*-zone here than at Pinhay, where we obtained a twice-checked measurement of $39\frac{1}{2}$ ft. Of course, it is possible that we failed to detect the strong nodular flint-line. When we describe the section at Annis' Knob it will be seen that we have no thin tabular flint-band to form the upper limit of the *Holaster planus*-zone, as at Pinhay, so we should hardly expect to have it here. Without the thin tabular flint-band it would be difficult to fix on the thick nodular flint-line 13 ft. below it, and it is therefore possible that there may be a thin cap of *Micraster cor-testudinarium*-chalk, though there is certainly no evidence of its existence.

Leaving the *Holaster planus*-zone, we note that at Connett's Hole we have a small fall chiefly consisting of large masses from the *Rhynchonella cuvieri*-zone, which well repay examination. A full day's work can be spent on these blocks alone. Behind these blocks is a turf-clad talus, from the top of which we can work the *Rhynchonella cuvieri*-zone *in situ*, and obtain another measurement of this chalk.

From the top of the Cenomanian Limestone to the first flint-line in the *Terebratulina gracilis*-zone . . $27\frac{1}{2}$ ft.

The first flint-line is a band of scattered flints 9 inches thick, which is 4 ft. below the lower member of the lower pair of yellow nodular bands described at White Cliff (p. 13). At the main White Cliff section the chalk is too obscured by rain-wash to enable one to readily collect the name-fossil of the *Terebratulina gracilis*-zone, but here we have no difficulty in tracing it down to the first flint-line; and as the zoological evidence coincides with the lithological division, we have no hesitation in fixing the base of the *Terebratulina gracilis*-zone at the first flint-line, as in the western sections of Pinhay Cliff and the Great Cleft. We had here the good fortune to find an example of *Micraster cor-bovis*, *in situ*, 3 ft. above the base of the *Rhynchonella cuvieri*-zone.

From this small fall at Connett's Hole to King's Hole the Chalk is inaccessible, and the fallen blocks are covered with sea-weed. It is perfectly safe to collect from these two falls, as the derivation of each block is obvious at a glance. We found it necessary to devote three days to White Cliff fall, and one to the smaller fall at Connett's Hole.

We now pass through the cave under the scar at East Ebb, noting that the sides are formed by Greensand and Cenomanian Limestone, and the roof by the zone of *Rhynchonella cuvieri*.

Beer Harbour, North Side.

Zone of Rhynchonella cuvieri.

If we stand well out on the reefs we see that the scar is capped by the zone of *Rhynchonella cuvieri* (Pl. VI), and that

the dip of the Beer syncline speedily brings the upper limit of that zone to the shingle.

From the top of the Cenomanian Limestone to the first flint-line in the *Terebratulina gracilis*-zone ...	25½ ft.

This zone is here much wave-worn, and is not a rich section for the collector.

Zone of Terebratulina gracilis.

Practically the whole of the northern side of Beer Harbour is cut in this zone, and the two bands of marly flintless chalk, the three strong flint courses, and the two pairs of yellow nodular bands can readily be traced. These lithological features have already been described on p. 13. If we follow the marl-seam, which separates the zones of *Terebratulina gracilis* and *Holaster planus* in the section between White Cliff and East Ebb, we notice that in Pl. VI this seam, and a small patch of *Holaster planus*-chalk, crown the cliff at the latter point. By tracing with the eye the direction of the marl-seam we find that the line of the grass slope at the top of the cliff pretty accurately marks the junction of the zones of *Terebratulina gracilis* and *Holaster planus*. We check the measurements which we obtained for the base of the *Terebratulina gracilis*-zone on the talus at White Cliff, and compare them.

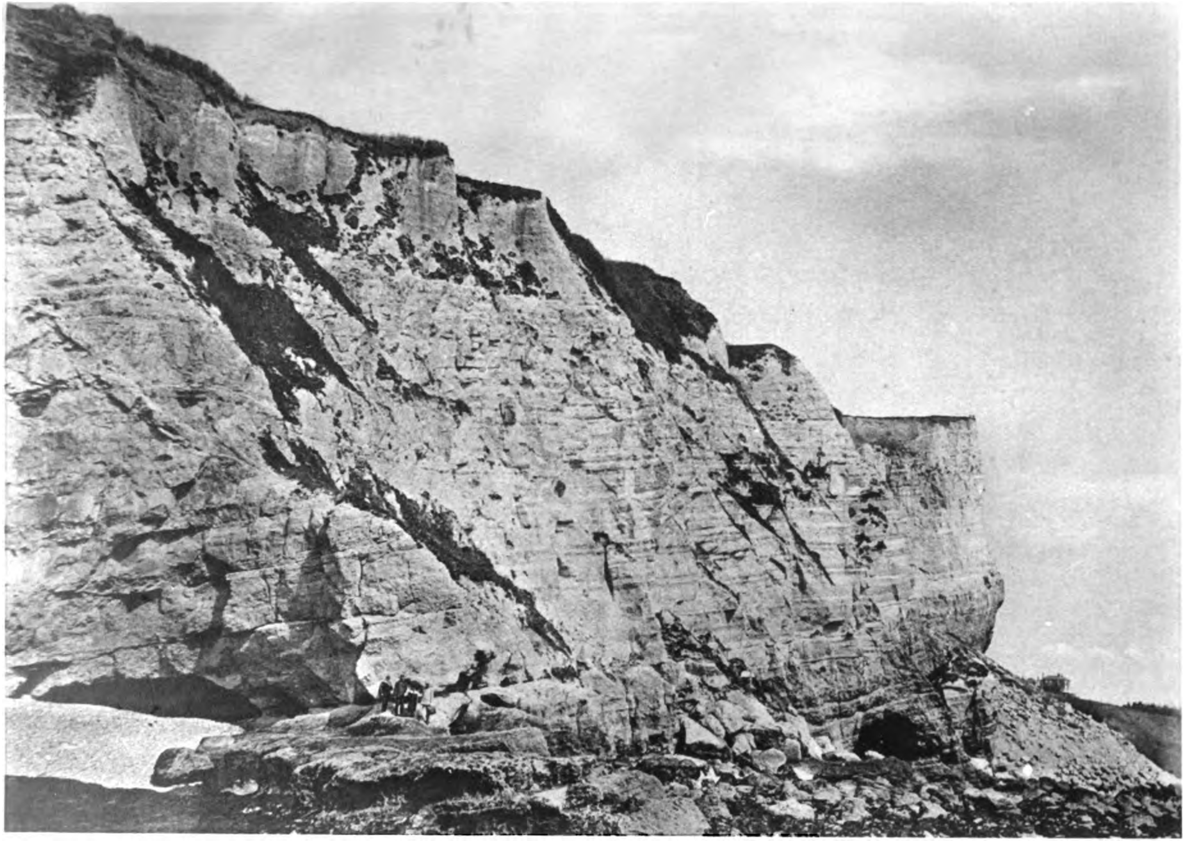
From the base of the 2-ft. band to the level which corresponds with the marl-seam dividing the zones of *Terebratulina gracilis* and *Holaster planus*	57 ft.
From the first flint-line in the *Terabratulina gracilis*-zone to the base of the 2-ft. marl-band	32 ft.
Total thickness of *Terebratulina gracilis*-zone ...	89 ft.

We notice that here the 2-ft. band is based by a strong nodular flint-line, and that the 4-ft. band is bounded below by two strong flint courses four feet apart. These features can be traced at White Cliff, Connett's Hole, and Hooken Cliff.

It is impossible to give a measurement which shall be fully satisfying and exact, for the reason that the actual junction between the zones of *Terebratulina gracilis* and *Holaster planus* is hidden by the grass slope. The whole of this section was measured twice, with the exception of the highest 15 ft., and that had to be guessed, as it was covered by the grass. The thickness is greater than that which we estimated at White Cliff, where we judge it to be about 70 ft.

Zone of Holaster planus.

Annis' Knob (Pl. VII) is the name given to the finely weathered bluff above the green slope. The cliff-path from Beer to Seaton passes along its foot. This bluff is interesting in that it



EAST EBB TO WHITE CLIFF FROM SCAR AT BEER HARBOUR.

the dip of the Beer syncline speedily brings the upper that zone to the shingle.

From the top of the Cenomanian Limestone to the first flint-line in the *Terebratulina gracilis*-zone ...	

This zone is here much wave-worn, and is not a for the collector.

Zone of Terebratulina gracilis.

Practically the whole of the northern side of Beer cut in this zone, and the two bands of marly flint three strong flint courses and the two pairs of yel bands can readily be traced. These lithological fea already been described on p. 13. If we follow the which separates the zones of *Terebratulina gracilis* and *planus* in the section between White Cliff and East notice that in Pl. VII this seam, and a small patch of *planus* chalk, crown the cliff at the latter point. By trac the eye the direction of the marl seam we find that the the grass slope at the top of the cliff pretty accurately m junction of the zones of *Terebratulina gracilis* and *H. planus*. We check the measurements which we obtained base of the *Terebratulina gracilis*-zone on the talus at White and compare them.

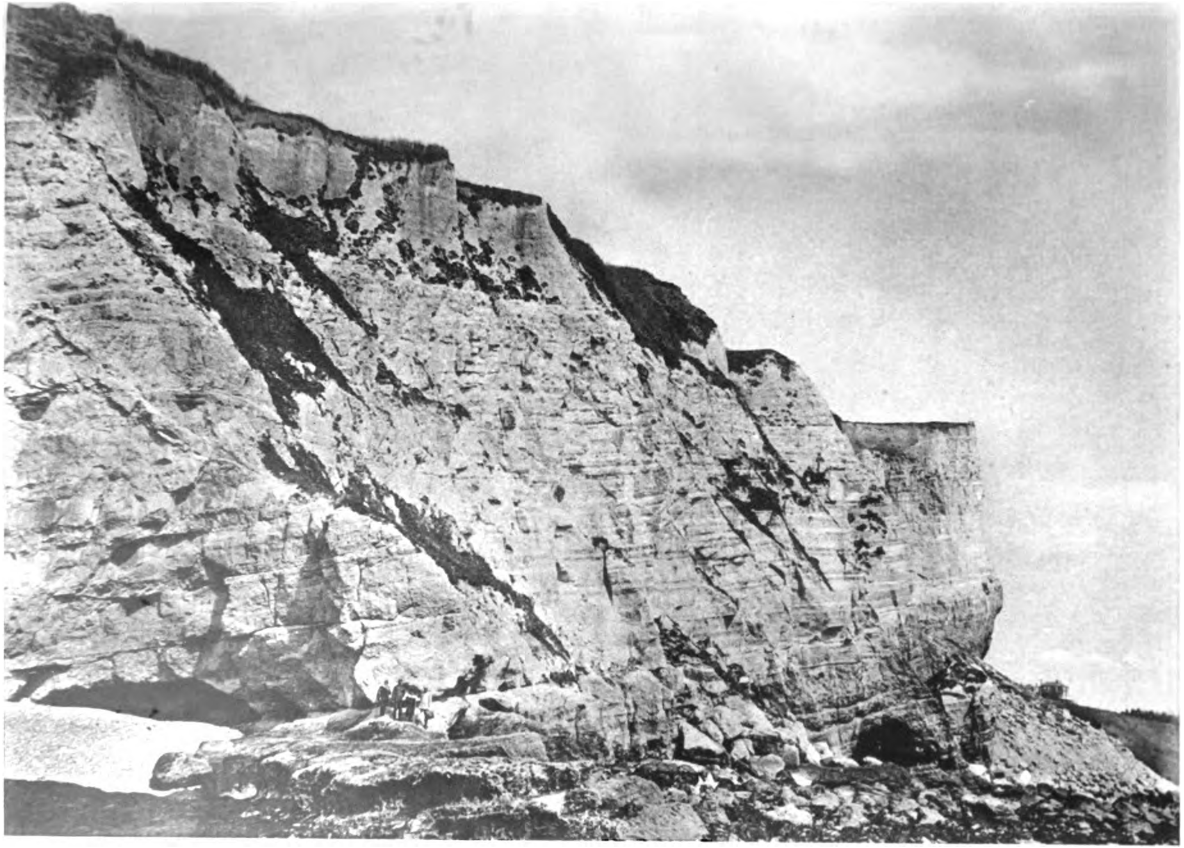
From the base of the band to the level which corresponds with the seam dividing the zones of *Terebratulina gracilis* and *Holaster planus*	57 ft.
From the first the *Terebratulina gracilis*-zone to the base of the 2-ft. marl-band	32 ft.
Total thickness of *Terebratulina gracilis*-zone ...	89 ft.

We notice that here the 2-ft. band is d by a s nodular flint-line, and that the ft. band is bounded below two strong flint courses four feet apart. These features can traced at White Cliff, Common's Hole, and Hooken Cliff.

It is impossible to give a measurement which shall be f satisfying and exact, for the reason that the actual junct between the zones of *Terebratulina gracilis* and *Holaster plan* is hidden by the grass slope. The whole of this section w measured twice, with the exception of the highest 15 ft., and th had to be estimated, as it was covered by the grass. The thick is greater than that which we estimated at White Cliff, where w make it to be about 70 ft.

Zone of Holaster planus.

Annis's Knob (Pl. VIII) is the name given to the fi weathered bluff above the green slope. The cliff-path from to Seaton passes along its foot. This bluff is interesting in that



East Ebb to White Cliff from Scar at Beer Harbour.

is practically the only accessible coast-section in this zone, save that at Pinhay Cliff. The eye is at once attracted by a strong nodular flint-line, which intersects the bluff rather more than half-way up. At the base of the bluff is another strong nodular flint-line, with a weaker one $1\frac{1}{2}$ ft. below it. The upper strong flint-line and the lower and weaker pair can be traced at Pinhay Cliff and Beer Head (pp. 5, 20), though the lower pair are not clearly shown in the former section. At Pinhay Cliff we have alluded to the fact that though the upper and stronger flint-line may be taken as a rough guide for separating the zones of *Holaster planus* and *Micraster cor-testudinarium*, the actual zoological division occurs at the level of a thin tabular flint-band which is 13 ft. above it. At Annis' Knob no trace of this thin tabular flint-band can be seen, but an ordinary nodular flint-line occurs at much the same level. This is worth noting, as at Beer Head the thin tabular flint band is clearly seen. It is only another instance of lithological features being inconstant even within a narrow area. We have alluded to the same thing in the Kent and Sussex paper on pp. 332, 336, *et alt.*

The air-weathering of this bluff is remarkable. We trace an abundant and characteristic fauna up to the level of the strong flint-line, half-way up the bluff, and are of opinion that here, as at Pinhay Cliff, the *Holaster planus* fauna is carried above it, for we find *Holaster planus* and *Micraster præcursor* of the group form characterised by "sutured" and "gently inflated" ambulacra, together with an occasional example of *Terebratulina gracilis*. That the boundary line between the zones of *Holaster planus* and *Micraster cor-testudinarium* should be purely zoological is nothing new, for we note the same thing at Beachy Head (Kent and Sussex, p. 326). In Dorset on the other hand, the naked-eye appearance of the two beds is so different that there is no difficulty in separating them at a glance, and it is of interest to note that there the lithological and zoological division coincides.

The measurements for the *Holaster planus*-zone at Annis' Knob are as follows:

From the upper of the two strong flint-lines about 10 ft. of chalk having a zoological affinity for the *Holaster planus*-zone	10 ft.
From the path to the upper of the two strong flint-lines .	20 ft.
From the supposed junction of the *Terebratulina gracilis* and *Holaster planus*-zones on the grass slope to the path	30 ft.
Total thickness . . .	60 ft.

The estimated junction of the zones of *Terebratulina gracilis* and *Holaster planus* on the grass slope is obtained by following with the eye the dip of the beds. In Plate VII the marl-band dividing these zones is seen at the extreme angle at the top of the

cliff, and by continuing this line along the grass slope we get the approximate spot from which we take the base of the *Holaster planus*-zone.

On the north side of the cliff-path from Seaton to Beer, east of Annis' Knob, is a small exposure of broken-up chalk. We assign this to the zone of *Micraster cor-testudinarium*, because therein we found two examples of *Micraster præcursor* of the group-form associated with that zone. This spot is indicated on Plate VII.

The measurement given for the *Holaster planus*-zone at Beer Harbour is 20 ft. more than that obtained at Pinhay Cliff, where we had the chance of securing a careful and accurate limitation of the upper and lower boundaries of this zone by rigid collecting. We know that we have 45-50 ft. in the second bluff S.W. of White Cliff, and that here the upper of the two strong flint-lines does not appear. Further, at Beer Head, this zone would appear to be at least 50 ft. thick, as far as the eye can gauge it from the top of the cliff. We, therefore, prefer to adhere to the figures as we now give them for Beer Harbour. In any case, throughout the whole of this coast, nothing is more certain than that the measurements of the zones will differ at various points, even in sections where accurate measurement is possible, and where lithological features can be checked by zoological data.

Zone of Micraster cor-testudinarium.

The remainder of Annis' Knob is cut in the zone of *Micraster cor-testudinarium*, for at about 10 ft. above the strong flint-line, which intersects the bluff, the *Holaster planus*-fauna is replaced by *Micraster præcursor* of the group-form characteristic of the higher zone. Both at Pinhay Cliff and Beer Head there is an open marl-seam about 6 ft. above the thin tabular flint-band, and this, like the tabular band, is absent at Annis' Knob (Plates VII, IX, X). There is 30 ft. of the *Micraster cor-testudinarium*-zone exposed in this bluff, and fossils can be collected by climbing the steep grass slopes on the western side.

Beer Harbour.—West Side.

Zone of Rhynchonella cuvieri.

Here again the bulk of the cliff is cut in the zone of *Terebratulina gracilis*, which is, however, nowhere accessible. Looking southward along the western side of Beer Harbour towards Beer Head, the beds appear to be horizontal, and the ledge of Greensand and Cenomanian Limestone juts out at the foot of the cliff

BEER HARBOUR, NORTH SIDE, FROM THE WEST.

as far as "The Hall." From the slipway nearly to the small fall we can examine the zone of *Rhynchonella cuvieri* from the beach, but as we work to the south the beach gets less steep, and the Cenomanian Limestone and Greensand come in. For some distance south of the small fall we can only examine the *Rhynchonella cuvieri*-zone by climbing upon the Greensand ledges. This exposure of the zone is less wave-worn than that on the north side of the Harbour, and is worth collecting from. It cannot, however, be considered to be a rich section. We are able to get a measurement of the *Rhynchonella cuvieri*-zone from the top of the small fall already mentioned.

From the top of the Cenomanian Limestone to the first flint-line in the *Terebratulina gracilis*-zone ... ... 20 ft.

This is a reduction of $5\frac{1}{2}$ ft. on that given at East Ebb, and $8\frac{1}{2}$ ft. on the White Cliff section, while it is $7\frac{1}{2}$ ft. less than that at Connett's Hole.

At Pound's Pool Beach are fallen blocks from the *Rhynchonella cuvieri*-zone, poor in fossils, and the caves have their walls cut in chalk of the same age.

From the top of the Cenomanian Limestone to the first flint-line in the *Terebratulina gracilis*-zone ... ... 20 ft.

The foreshore at Pound's Pool is strewn with fallen blocks, but these at the time of our visit could not be examined on account of the tide. Above Pound's Pool Beach is an inaccessible slipped face of the *Holaster planus*-zone. A good view of this section can be obtained at the top of the cliff, through a gap in the hedge. A little farther south is a small exposure of the same zone, which would be accessible to a good climber. We know the horizon of this bluff, because, by reaching down over the edge of the cliff, we obtained a typical example of *Micraster præcursor* of the group-form characteristic of this zone.

About 250 yards north of the point of Beer Head, at the top of the cliff, is a cleft which is easy of access. The cleft is double, and the seaward division at a lower level than the landward. From the higher exposure we obtained a good list of fossils characteristic of the *Micraster cor-testudinarium*-zone, especially of *Micraster præcursor*, with strongly "inflated" or feebly "subdivided" ambulacra, whereas, in the lower or seaward cleft, this urchin was much rarer, and the ambulacra smoother and less angular in section, and one example of *Terebratulina gracilis* was found. We have here, therefore, an exposure of the junction of the zones of *Holaster planus* and *Micraster cor-testudinarium*, and in the higher cleft of the base of the latter zone alone. *Holaster planus* was not found in the lower cleft, but *Holaster placenta* was not uncommon, and we had the good fortune to secure an example of the beautiful little rotiform Bryozoon alluded to on

p. 23 of the Dorset paper. Its chief horizon is in the *Holaster planus*-zone, though we have found it in the zone of *Micraster cor-testudinarium* at Dover.

BEER HEAD.

We can reach Little Beach either by boat from Beer, or by descending from South Down Common by the path leading to the landslip called Under Hooken. The so-called path to the shore from the undercliff level is at the east side of Under Hooken, and we have marked its position by an arrow on Plate X. In passing down this path to the shore we can reach an air-weathered surface of the *Rhynchonella cuvieri*-zone, and obtain a measurement of it.

From the top of the Cenomanian Limestone to the first flint-line in the *Terebratulina gracilis*-zone . . . 16 ft.

It will be noticed that this measurement is $12\frac{1}{2}$ ft. less than that recorded at White Cliff.

We now face the fine promontory of Beer Head, shown in Plate IX, which gives us a range from the Upper Greensand to the zone of *Micraster cor-testudinarium.* The key-plate enables us to trace every lithological detail in this magnificently weathered surface. No section on this coast gives one so diagrammatic an idea of the zonal boundaries as Beer Head, for none is so complete. We may even go further, and assert that there is no section on the English coast which gives so much zonal detail, or tells the story of zonal succession in so convincing and graphic a manner. There is here an unbroken exposure, 200 feet in height, wherein we can clearly define the *Rhynchonella cuvieri*-zone, and all the features of the *Terebratulina gracilis*-zone which we have recorded at White Cliff (Pls. V and VI). We also note the marl-seam dividing the zones of *Terebratulina gracilis* and *Holaster planus*; the strong flint-line near the top of the latter zone; the thin tabular flint-band which divides it from that of *Micraster cor-testudinarium*; and the marl seam higher still in the last-named zone The latter features are best examined from the top of the cliff, on the west side of the headland. Though we cannot measure the beds, it looks as if the distances between all the lithological features in the zones of *Holaster planus* and *Micraster cor-testudinarium* were more spaced-out than at Pinhay Cliff. At this point there would seem to be not less than 50 ft. of the former zone, and about the same thickness of the latter as here exposed.

At low water one can round Beer Head from the west, and work the fallen blocks from the zones of *Rhynchonella cuvieri* and *Terebratulina gracilis.* Such of them as we had time to examine were dirty, and not very rich in fossils.

Beer Harbour, West Side, from the North.

Being on the shingle we will now pass westward, and examine the rock-strewn shore of Hooken Beach. The chalk cliffs here are all slipped faces from the zones of *Rhynchonella cuvieri* and *Terebratulina gracilis*. Some of the Greensand masses are rich in fossils to a remarkable degree, and the same remark applies to the Cenomanian Limestone. Two full days' work can be spent in collecting from the fallen blocks from the zones of *Rhynchonella cuvieri* and *Terebratulina gracilis* alone. Those from the former zone are particularly rich in examples of *Echinoconus castanea*, for we found thirty here in one day.

Still walking westward we come to a path which leads from the shore to the potato gardens, and by this we can enter Under Hooken again. This path is situated a few yards to the west of the last rocks on Hooken Beach, and it is important not to miss it, as there is no other means of entering the undercliff, and nothing but a heavy shingle beach between this point and Branscombe.

Under Hooken and Hooken Cliffs.

We notice at once that the Pinnacles are merely slipped masses from the parent cliff (Pl. X). They show a section from Greensand to the zone of *Terebratulina gracilis*. In them the zone of *Rhynchonella cuvieri* is badly displayed, but excellent collecting may be had from the *Terebratulina gracilis*-beds, particularly from the most northern Pinnacle, which can be worked on all sides. Unfortunately, the seaward face of the southernmost Pinnacle, which is finely weathered, is inaccessible at the base, which is cut in the zone of *Rhynchonella cuvieri*.

Standing at the east side of the Hooken and facing the cliffs, we see two air-weathered bluffs on the path which leads up to South Down Common. They are *in sitû*, and project beyond the turf slopes, being continuous with the cliff of Beer Head on the east. Unfortunately, none of our plates show these bluffs, but their position is so obvious that no mistake can be made in locating them. They are both cut in the zone of *Terebratulina gracilis*, and the lower one is particularly rich in large examples of the name-fossil of this zone. Its position in the zone is clear, for it is well above the 4-ft. band of flintless marly chalk (Pl. IX). The higher bluff is practically a direct continuation upwards of the lower, and brings one almost to the upper limit of the zone. The chalk at the apex of the higher bluff is greyish, and the flints more widely separated. At the first glance it looks as if it belonged to the *Holaster planus*-zone, but by leaning over the top of it we removed three examples of *Micraster cor-bovis*, but could find no trace of *Micraster leskei* or *Micraster præcursor*. Bearing in mind the data obtained in the western part of Pinhay Cliff (p. 7), we have no hesitation in assigning the top of this bluff to the zone

of *Terebratulina gracilis* rather than to that of *Holaster planus.* Moreover, the marl-seam dividing these zones is not seen, though it is clearly defined in Beer Head itself (Pl. IX). It may be mentioned that the upper part of this small exposure is singularly rich in fossils, and yielded us a characteristic fauna of the upper part of this zone. From it we collected ten examples of *Micraster cor-bovis*, and one of *Pecten pexatus**, Woods.

Below the higher bluff on the path is an extensive, if somewhat disconnected, section of the *Terebratulina gracilis*-zone on the steep turf slope. The eye is at once attracted by the unusual thickness of the zone in question at this point, and it is clearly worth while to obtain a measurement of it. The beds extend in practically an unbroken succession from the top of the *Rhynchonella cuvieri*-zone, by the path leading to Hooken Beach, to the apex of the higher bluff on the path leading to South Down Common. With the assistance of Dr. F. L. Kitchin we secured a measurement of this surface of 156 ft. 3 in. When we contrast this with the 70 ft. (estimated) at White Cliff, and the 89 ft. at Beer Harbour, we see a remarkable thickening of this zone in a comparatively short distance.

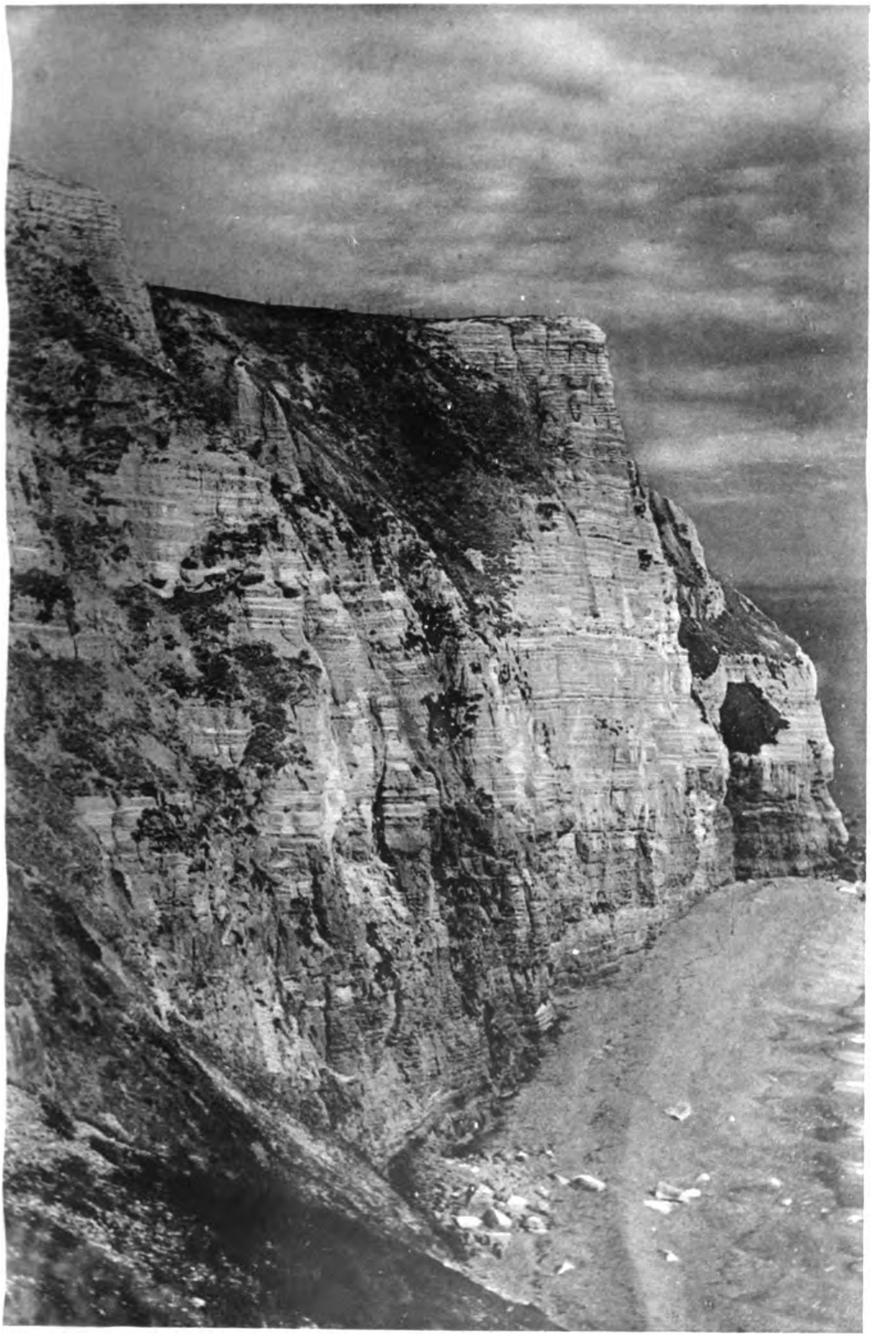
To the west of the lower bluff on the pathway, and above it, we see a small triangular surface of greyish chalk, which we assign either to the base of the *Holaster planus*-zone, or to the top of the bed of *Terebratulina gracilis*, though the evidence is in favour of the latter. The only fossil obtained from it was an example of *Holaster planus.*

We now stand on the high ground on the north side of the Pinnacles, and examine the main cliff from the old turf-clad talus to beyond the adit for Beer-stone. The positions of both the talus and the adit are indicated on Plates X and XI. Ascending this talus we can get a measurement of the *Rhynchonella cuvieri*-zone and of the lower beds of that of *Terebratulina gracilis.*

From the first flint-line in the *Terebratulina gracilis*-zone to the base of the 2-ft. band of marly flintless chalk...	24 ft.
From the top of the Cenomanian Limestone to the first flint-line in the *Terebratulina gracilis*-zone	24 ft.

It will be remembered that we obtained measurements of the *Terebratulina gracilis*-chalk below the 2-ft. band of marly and flintless chalk at White Cliff and Beer Harbour, which were respectively 35 ft. and 32 ft. The position of the 2-ft. and 4-ft. bands is chiefly indicated in Pl. XI, as well as that of the *Rhynchonella cuvieri*-zone, here 24 ft. in thickness. Though the latter bed appears to be well weathered, it is very disappointing to the collector.

* Pal. Soc., vol. lvi, 1902, p. 190, Pl. xxxvi, figs. 5-7.



Beer Head, from the West.

In Plates X and XI are seen at the top of the main cliff three small triangular exposures, marked with a + on the key-plate. To the eye these appear greyish in colour, and there is a faint indication of a marl-seam intersecting them. At the first glance they would appear to be in the base of the *Holaster planus*-zone, with the marl-seam dividing this zone from that of *Terebratulina gracilis*. If we carry the eye to the east, however, taking the apex of the higher bluff on the path, which we know to be in the top of the *Terebratulina gracilis*-zone, as our datum-line, it is clear from the dip of the beds that these three surfaces are more probably in the rugged and greyish chalk which we have shown to belong to the upper limit of the latter zone (pp. 7 and 21).

A little west of the adit for Beer-stone is a fallen mass, south of the path leading down the slope from Under Hooken to the potato gardens. This block is based in Cenomanian Limestone, and capped by *Terebratulina gracilis*-chalk, and shows a well-weathered section of *Rhynchonella cuvieri*-zone, measuring only 14 ft. in thickness. This is the smallest measurement which we have obtained for this zone. The adit for Beer-stone is a useful guide to the base of the *Rhynchonella cuvieri*-zone, and helps one in carrying the eye westward along this particular horizon (Pl. XI).

We now leave this section and go westward to the potato gardens, in order that we may examine the chalk overlying the Greensand in Hooken Cliff and Branscombe Cliff. Under the signal the cliffs are sheer, and the chalk inaccessible. As far as one can estimate with the eye, there appears to be no loss in thickness here of the *Rhynchonella cuvieri*-zone, much less in that of *Terebratulina gracilis*. Opposite the Tombstone there must be 20 ft. of the *Rhynchonella cnvieri*-zone in the cliff, but between that point and Martin's Rock, which are both marked on Sheet 83, S.E., of the 6-in. Ordnance Survey Map, the lower beds rapidly thin out, and opposite the latter landmark we have lost the Cenomanian Limestone, the whole of the *Rhynchonella cuvieri*-zone and the lower beds of the *Terebratulina gracilis*-chalk. Some 250 ft. east of Martin's Rock about 10 ft. of the *Rhynchonella cuvieri*-zone is still showing, and this gives one some idea of the rapidity with which the beds are thinning out at this point.

At the talus east of the adit for Beer-stone we obtained a thickness for the *Rhynchonella cuvieri*-zone of 24 ft., and of the *Terebratulina gracilis*-zone, up to the 2-ft. band of marly and flintless chalk, of 24 ft. At Martin's Rock the 2-ft. band rests on the Greensand itself (Pl. XII), and farther west still more of the *Terebratulina gracilis*-zone has gone, for we find that the 4-ft. band is comparatively close to the Greensand. This 4-ft. band was about 25 ft. above the 2-ft. band at White Cliff, and is probably much higher here, as the zone has thickened. Mitchell's

Rock, which is a fallen mass on the footpath, and not marked on the map, shows the *Terebratulina gracilis*-chalk resting on the Greensand, without any Cenomanian Limestone intervening. This rock is a few yards to the east of the boundary line between the parishes of Beer and Branscombe. The boundary stone is at the top of the cliff, and the line from this terminates at the stile on the footpath in the potato gardens. We have, therefore, lost between the Tombstone and Mitchell's Rock

Rhynchonella cuvieri-zone	24 ft.
Terebratulina gracilis-zone up to 2-ft. band	24 ft.
" " " up to 4-ft. band, about ...	25 ft.
	73 ft.

This calculation does not take into consideration the loss of the Cenomanian Limestone or any of the Greensand, and we leave the estimated loss of these beds to those within whose province they fall.

This disappearance of the zone of *Rhynchonella cuvieri* and part of that of *Terebratulina gracilis*, together with some of the series underlying the White Chalk, affords an interesting and curious example partly of contemporaneous erosion, and partly of cutting off of beds by deposition against a Greensand slope. We had the advantage of discussing this question with Mr. Jukes-Browne some three years since, and this, as far as we can remember, was the conclusion arrived at by him. For our part, we see no other explanation of this curious problem, and give our adhesion to it as the only solution which in any way meets our views. That the *Terebratulina gracilis*-chalk as a whole does not thin out may be inferred from the fact that these beds measured 156 ft. in the Hooken, as against 89 ft. at Beer Harbour, 70 ft. (estimated) at White Cliff, and 71 (as exposed) at Pinhay Cliff. Moreover, that the loss of this considerable thickness of material is but local is proved by the fact that we have found *Rhynchonella cuvieri*-chalk in two places on the high ground on the east side of Branscombe Valley, and that it comes in again in increased thickness at Branscombe West Cliff. We have seen evidences of erosion along the whole section in the presence of chalky beds with glauconitic grains in which is a mingled fauna from Cenomanian Limestone and the lower bed of the White Chalk. Thus, the remanié bed which represents, under the name of Cenomanian Limestone, the Grey Chalk and Chalk Marl, is not the only evidence of actual erosion, and both the factors of erosion and cutting off of beds by deposition against a Greensand bank must be employed to explain the whole chain of phenomena as they apply to the basal beds of the White Chalk.

HOOKEN CLIFF, UNDER HOOKEN, AND PINNACLES, FROM THE EAST.

Branscombe and Berry Cliffs.

We cross the little stream which runs out at Branscombe Mouth, by passing over the footbridge, and then ascend the steep slopes of Branscombe West Cliff. Arriving at the summit we find a small but well weathered exposure of flintless chalk capped by flinty chalk, the two sides of which face south and east. The flintless chalk is nodular, and presents many of the characteristic lithological features of the *Rhynchonella cuvieri*-zone, but there are softer beds in it than we are accustomed to on this coast. This bed is rich in fossils, but we note that *Inoceramus mytiloides* is not present, that *Rhynchonella cuvieri* is notably rare, and that *Discoidea dixoni*, *Hemiaster minimus*, and *Cardiaster pygmæus* are but poorly represented. Further collecting in this flintless chalk shows us that *Echinoconus castanea* and *Cardiaster cretaceus*, which are so common in the western part of this zone, are not found at all. This is the fauna which we have hitherto met with along this coast, and regarded as characteristic of the zone in question; but it is here replaced by a wealth of spines, and even segments or complete tests, of *Cidaris hirudo* and *Cidaris clavigera*. In addition, the columnars of *Pentacrinus* of small size are very common, forming quite a little band farther west, and ossicles of asteroids abound. Spines of *Cidaris hirudo* have been met with all along the section, from Pinhay to the Hooken, becoming commoner as we pass westward, but now they seem to be the dominant fossil. We have not found spines of *Cidaris clavigera* east of Seaton, and the first record which we have of it is at Connett's Hole. It is certainly not uncommon at Hooken Beach, but it only reaches its true development at Branscombe and Berry Cliffs. One test of this rare urchin was found on the northern face of the most western pinnacle. We spent a whole morning searching for it on the fallen blocks at White Cliff, and failed to find it.

Crowning the flintless chalk is a soft, marly, flinty chalk, in every way similar to that assigned to the *Terebratulina gracilis*-zone in all other parts of the section. We collect from it, and obtain two examples of *Terebratulina gracilis* $1\frac{1}{2}$ ft. above the first flint-line, and note that it is abundant 3 ft. above the same mark, and of large size. Whatever may be the faunal peculiarities of the zone below, it is clear that the *Terebratulina gracilis*-zone, as here exposed, conforms both lithologically and zoologically to its normal. This surface yielded us three examples of *Echinoconus subrotundus*.

From the first flint-line to the top of the bluff .	about 35 ft.
From the top of the Cenomanian Limestone to the first flint-line in the zone of *Terebratulina gracilis* .	. 20 ft.

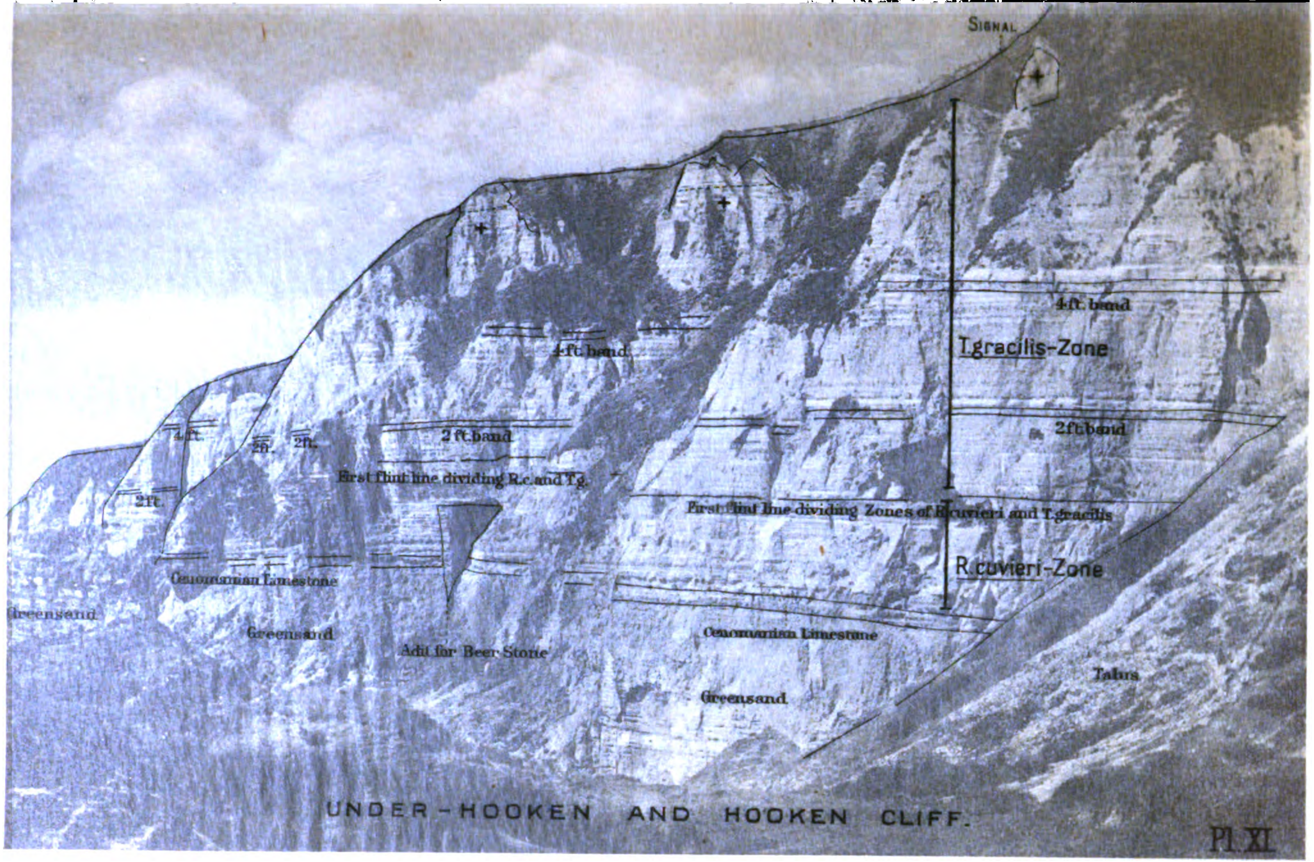
We have, therefore, in this bluff 20 ft. of flintless *Rhynchonella*

cuvieri-zone with a bastard fauna, and 35 ft. of *Terebratulina gracilis*-chalk, as here exposed, with a normal fauna.

There is no evidence here of the presence of the two pairs of yellow nodular chalk bands at the base of the *Terebratulina gracilis*-zone, which we have noted at White Cliff and Beer Harbour, nor is the 2-ft. band of marly flintless chalk seen. The latter is situated 35 ft. from the base of the zone at White Cliff, and 48 ft. at the Hooken (p. 22). It will be remembered that they are not in the usual position at Pinhay Cleft (p. 9), even if they exist there at all; but they would appear to be present at the entrance to the Dowlands landslip, on the north side of the road leading to the great gap. Indeed, throughout the whole coast there are few lithological features upon which we can depend for more than a quarter of a mile. This remark applies to flint-lines and marl-bands, and it relates with equal truth to the measurement of the zones.

Hitherto, however, we have always found on this coast that whatever may be the lithological facies of any given zone, that particular facies is constant throughout the section. Here, at Branscombe West Cliff, on the contrary, this element of certainty in defining a zone by its gross lithological appearance utterly fails us, for we have a considerable thickness of soft flinty chalk, seamed here and there with harder iron-stained nodular bands, which so closely resembles that of the *Terebratulina gracilis*-zone that we should unhesitatingly refer it to this horizon did not the fossils entirely prohibit such a course. The chalk is so soft that we can often remove the fossils with a knife.

From Branscombe to Berry Cliff we see only one more exposure of the flintless *Rhynchonella cuvieri*-chalk, but all the little cappings of the cliffs are in flinty chalk. With the exception of the tops of the first two or three bluffs we have no evidence of the occurrence of a normally developed *Terebratulina gracilis*-chalk, the whole of the remaining flinty chalk failing to yield a single example of the name-fossil of this zone. We are, therefore, confronted with the fact that we have here a considerable thickness, probably reaching a measurement of 50-60 ft., of flinty chalk which we must assign to a zone which is not that of *Terebratulina gracilis*. This flinty chalk is uniform zoologically with the flintless chalk at Branscombe West Cliff, for it is crowded with remains of *Cidaris hirudo* and *Cidaris clavigera*, while the other characteristic fossils of the *Rhynchonella cuvieri*-zone are either absent or but sparingly represented. As in the flintless chalk, there is a band of small ossicles of *Pentacrinus*, and the ossicles of Asteroidea are found in remarkable profusion. As mere lithological conditions are of no weight compared with definite zoological evidence, it is clear that we have no choice but to assign both the flinty and flintless chalk yielding this peculiar fauna to the zone of *Rhynchonella cuvieri*.



UNDER HOOKEN AND HOOKEN CLIFF, FROM THE EAST.

We find no thickening of the flintless member of this bastard *Rhynchonella cuvieri*-zone, for at Berry Cliff, where the sequence is well shown, it does not appear to be of greater extent than at the top of Branscombe West Cliff. The increase in thickness is due entirely to the addition of the flinty member of the zone, measuring probably not less than 60 ft.

We have, then, west of Branscombe a section of the *Rhynchonella cuvieri*-zone bastard in its fauna, and abnormal in its lithological features, which is not only absolutely different to anything else on this coast, but quite without parallel in England. In its profusion of *Cidaris* remains it would seem to resemble the beds of *Cidaris hirudo* of the Yonne.

These cliff-top exposures are not easy to find, and the best way, until one learns the undercliff paths, is to keep along the top of the cliff, and to descend to any accessible face which is seen. The first opportunity occurs 50 yards to the west of the gate at the western end of the coppice. We here find a small but beautifully weathered section on the footpath below the cliff top, which is a counterpart of the exposure facing south and east at Branscombe West Cliff. The main exposures are reached by taking the track through Old Quarry Workings, marked on the 6-inch Ordnance Survey Map, 83 S.E. All these later exposures are in the flinty *Rhynchonella cuvieri*-chalk. Tracing these sections, until the path ceases, we arrive at a spot where the flintless chalk forms a natural arch at the lower cliff edge. We estimate that we have here a combined thickness of flintless and flinty *Rhynchonella cuvieri*-chalk of 58 ft., as exposed. A little farther west we see an inaccessible section displaying the whole sequence of beds, and probably giving 20 ft. of flintless and 60 of flinty chalk.

Crossing over the highest part of Berry Cliff we dip into Littlecombe Hollow, with its tumuli at the cliff top, and descend to Donkey Linhay Rocks. The Greensand Cliff to the north of these rocks is capped by about 30 ft. of chalk, equally divided between the flinty and flintless beds. On the western side of Littlecombe Hollow the high cliff is capped by a patch of chalk, probably in the *Rhynchonella cuvieri*-zone.

We can now work back to Branscombe along the main footpath on the undercliff, examining fallen masses on our way, and reaching the top of the cliff at the spot where we began our survey. There is a spring of good water on the 100 ft. contour line, below spot marked on the map as Old Quarries.

CHALK PITS IN THE BEER DISTRICT.

There are very few pits near the coast, and we only had time to examine the celebrated Beer Quarries and the old workings in Court Barn Lane, respectively one mile and three hundred yards from Beer.

Beer Quarry.

These quarries are worth a visit, more, perhaps, from the standpoint of general interest than from that of the collector. The Beer-stone is about 11 ft. thick, and is easily worked with a saw. Blocks weighing six or eight tons are common, and the stone works very free to the tool, but hardens on exposure to the air. The quarries are said to be of great antiquity, and the stone has been used in Exeter Cathedral and many of the Devonshire churches. In the Cathedral archives the stone is mentioned from 1427 to 1434 as being used for the building of the Chapter House. The stone has good resisting powers, as one can see by examining buildings in the neighbourhood. Occasionally a soft block has been used, and it is interesting to note that the weathering betrays the peculiar and characteristic appearance of the zone of *Rhynchonella cuvieri.* This freestone is indeed the basal bed of that zone, and yields the fossils associated with that horizon.

The freestone can hardly be said to be represented properly at Beer Harbour, and though it is better shown in the Hooken, where the adit for working it still exists, it has nothing like the thickness of that at the quarries. A trade pamphlet was published in 1882 by Mr. P. E. Masey, M.R.I.B.A., on Beer Stone, which gives much interesting information of its use in churches, though the palæontology is hardly above reproach.

The zones exposed at Beer Quarries are those of *Rhynchonella cuvieri* and *Terebratulina gracilis.*

We examined numerous small exposures in the neighbourhood, mostly in disused and grass-covered workings, simply for zoning purposes, but none of them are worthy of a visit with a view to collecting fossils. In the *Rhynchonella cuvieri*-zone a pit north of Bovey Coppice, and one in the Rookery, Bovey House; while in that of *Terebratulina gracilis* two pits at Lower Gatcombe, one at Couchill Farm, and another north of Bovey Coppice may be mentioned.

Court Barn Lane Quarry.

This is a double pit, and not now worked, one portion being used as a tip for the refuse of Beer Village. We regret that we could not give photographs of this pit and Beer Quarries, but the necessary illustrations for the coast sections have been so numerous that we have had to abandon the idea.

This surface is fairly weathered in parts, and by climbing the steep talus, one can obtain an accurate zoological division between the portions of the zones of *Terebratulina gracilis* and *Holaster planus* which are exposed. In the base of the section we notice that the flint-lines are placed at wide intervals, and that the chalk

Hooken Cliff from Martin's Rock.

is nodular, as at Pinhay Cliff. There is here no open marl-seam dividing the two zones as at Pinhay and White Cliff, but there is an indication of a very thin and indistinct marl-seam under a flint-line which crosses the middle of the section in the upper pit. Below this level we found six examples of *Micraster cor-bovis*, three of *Holaster planus*, an abundance of *Terebratulina gracilis*, but no other *Micraster*. This line is, therefore, clearly the zoological division between the two zones mentioned, each zone being exposed for about 24 ft.

LITHOLOGICAL SUMMARY.

With the exception that the base of the *Rhynchonella cuvieri*-zone develops into a freestone in the shape of the familiar building rock known to the trade as Beer Stone; that at Branscombe the same zone has the unique characteristic of being divided into flintless and flinty chalk; and that the zone of *Terebratulina gracilis* is one of the flintiest chalks which we have examined, there is little which calls for extended notice, or comparison with the beds in other coast-sections.

Zone of Rhynchonella cuvieri.

The chalk of this zone in a measure conforms to that in other counties, in that it has intensely hard bands interspersed, at irregular intervals, with belts of comparatively soft chalk in which no nodules occur, the harder chalk usually becoming more marked towards the base of the bed. We refer to what we may call the normal beds of the zone, which extend from Pinhay Cliff to the Hooken, where it is, like all other coast-sections which we have examined, a flintless chalk. Fragments of *Inoceramus mytiloides* are more abundant at the base of this zone, but Dover still remains the only coast-section where the "Grit-bed," or Melbourn Rock, is actually developed. The best example of the irregular arrangement of nodular and non-nodular bands is seen at Pinhay Cliff and Whitelands, where the contrast between the two types of chalk is most marked. In the western part of the section the beds are much condensed, and the zone in its entire thickness is intensely hard, marly, ironstained, and ringing to the hammer. The peculiar freestone bed called Beer Stone is alluded to on p. 28.

What we may call the abnormal *Rhynchonella cuvieri*-chalk of Branscombe and Berry Cliff, where the flintless chalk passes up into a thick belt of flinty chalk, has been described in detail on p. 26. This is, as we have already remarked, the only instance

known to us in this country where the blending of flinty with the normal flintless chalk occurs in the zone in question.

Zone of Terebratulina gracilis.

This chalk would readily prove a stumbling-block to the geologist who is content to divide his beds into chalk with flints and chalk without flints. In pre-zonal days this bed would be summed-up at a glance as "Upper Chalk," for it is generally recognised that the flinty beds usually occur high in the series. In southern coast-sections we know nothing comparable to the abundance of flints as seen in this zone in Devon. The flints are not in tabular bands, but in the shape of nodular and digitate masses, forming well-marked courses. At Dover there are several strong flint-lines in this zone, but in Sussex and Dorset they are absent. The chalk is firm, marly, and massive, and so conforms in appearance to all other exposures on the coast which we have described; but with the exception of the marl-seam dividing this zone from that of *Holaster planus*, there are no marl-bands which weather-out as open seams, like those at Dover.

Zone of Holaster planus.

Like all other sections of this zone, this is markedly nodular in appearance, and this condition can be well studied at Pinhay Cliff and Annis' Knob. Indeed, if we were asked to indicate an exposure where nodular-chalk could best be photographed we should unhesitatingly point to the latter situations as being almost diagrammatic in its display of this peculiar character. The flint-lines are strong, and irregular in their disposition, and the chalk is of a somewhat grey tint from admixture with marl. As in most other sections of this zone there are phosphatic and glauconitic nodules scattered throughout its thickness, and the bands of nodular chalk are intensely hard, and of a semi-crystalline nature. The flints are sometimes spongiform. From base to top of this zone, so clearly defined at Pinhay Cliff and Annis' Knob, are seen these hard nodular bands; but, though we made a special search, we were unable to set apart any special band, or series of bands, which could be defined as Chalk Rock. As we have already shown (p. 8) our record of the Gasteropod fauna is limited to one example of *Pleurotomaria perspectiva* and two of *Turbo gemmatus*, and Cephalopods are unrepresented. It will thus be seen that the Chalk Rock is absent both in its zoological and lithological sense. We institute no comparison between the chalk of this zone in Devon with that of Sussex or Dorset, because it practically agrees with them in all essential features.

It will be remembered that at Dover the Chalk Rock is represented in its zoological sense alone.

Zone of Micraster cor-testudinarium.

The chalk of this zone is also quite characteristic, and agrees in every essential point with all other exposures which we have described. The presence of several marl-bands is unusual, though we have recorded the same feature in Sussex. The bands of yellow nodular chalk, which are so characteristic, are here seen in a state of strong development, notably in the highest band displayed in Pinhay Cliff and the Chapel Rock. Here also the flints are arranged in irregular courses, and are sometimes spongiform. The chalk in the nodular bands is intensely hard and semi-crystalline, and is difficult to distinguish from that from the same bands in the bed below.

ZOOLOGICAL SUMMARY.

If this coast exhibited but one zone of the White Chalk, and that the beds of *Rhynchonella cuvieri*, it would be worthy of repeated visits, for this horizon is so rich in organic remains, and the fossils themselves are in many instances so unusual, that the chalk has not its counterpart anywhere on our shores.

We shall follow the methods employed in our previous papers, and give a tabular and detailed summary of the zonal guide-fossils. It must be understood, however, that each tabular summary applies to the Devon coast alone, and that the zoological data are of necessity imperfect, as they represent but the results of two visits to this district. The zone of *Terebratulina gracilis*, though not so unique in its fauna, is also singularly rich in fossils, and merits special attention. As the Dover section alone exhibits these two zones in perfection, we devoted our holiday in the autumn of 1901 to that coast, to the end that we might be able to compare the faunas of these two favoured localities. It is felt that comparisons such as these will bring out the wonderful way in which zonal guide-fossils hold good over wide areas, and at the same time draw attention to the equally interesting local variations in geographical distribution.

We have shown (pp. 8, 25) that the normally developed zone of *Rhynchonella cuvieri* extends from Pinhay Cliff to the Hooken, and that there is an exposure of this bed at Branscombe and Berry Cliff which, both in its lithological and zoological sense, depart from the normal. To avoid confusion we shall give a separate zonal summary for each of these remarkable divergent faunas.

Zone of Rhynchonella cuvieri.

[PINHAY CLIFF TO THE HOOKEN.]

Rhynchonella cuvieri *Inoceramus mytiloides* *Discoidea dixoni* *Cardiaster pygmæus* *Cardiaster cretaceus* *Hemiaster minimus* *Echinoconus castanea* *Salenia granulosa* *Glyphocyphus radiatus* *Cidaris hirudo* *Ammonites peramplus* *Serpula avita*	Fossils found throught the zone. Maximum thickness of the zone at Pinhay Cliff, 59½ ft.

Other characteristic fossils are: *Echinoconus subrotundus*, *Cyphosoma radiatum*, *Pentacrinus*, and *Terebratula semiglobosa* var. *albensis*.

Rhynchonella cuvieri is abundant from base to top of the zone, both in Devon and Kent, and sometimes reaches a large size, measuring as much as 19 or 20 m.m. in diameter. The large examples are perfectly true in shape, and in no way resemble *Rhynchonella plicatilis* or *Rhynchonella woodwardi*. It is only right to mention that these large forms are quite the exception.

Inoceramus mytiloides is most abundant at the base of the zone, but extends to the top, and into the lower part of the zone immediately above, both in Devon and Dover. We have already mentioned that there is no "Grit-bed" in Devon, such as is so well developed on the coast of Kent. *Inoceramus lamarcki* is common in both counties, especially in Devon, while *Inoceramus brongniarti* is a rare fossil recorded only for Dover.

But it is in Echinoderma that the chief interest lies, especially in Devon, and our only regret is that the obdurate nature of the matrix prevents these beautiful fossils from being properly displayed.

Discoidea dixoni in both counties is abundant, and is perhaps the only associated guide-fossil which we can always count on finding in poor exposures of this bed. It ranges in unbroken profusion throughout the extent of the zone, passing up in slightly diminished numbers to the top of the zone of *Terebratulina gracilis*.

Cardiaster pygmæus, Forbes,* is evenly distributed throughout this zone in Devon, whereas at Dover it is mostly found in the base of the bed—the "Grit-bed"—and is rare above that limit.

* M. Jules Lambert tells us that the proper designation of this species is *Cardiaster truncatus*, Goldf. See *Spatangus truncatus*, Goldf., Petref. Germ. i, 152, t. 47, f. 1.

We desire to correct a mistake in the distribution of fossils made on p. 318 of the paper on Kent and Sussex. Subsequent collecting fails to establish the occurrence of this urchin in the zone of *Terebratulina gracilis* in either Devon or Kent.

Cardiaster cretaceus,* Sorignet. To M. Jules Lambert, who is about to describe this fossil from material supplied by us from this section, we owe the determination of this species. Without, therefore, entering into any anatomical details we will say that it can readily be distinguished from *Cardiaster pygmæus* by its large size, which often reaches that of an *Holaster planus* of moderate dimensions. In Devon this urchin ranges throughout the extent of the zone, and passes up into the lower part of the zone immediately above. It may be described as abundant. Its geographical range in England must be very restricted, for we only know of two other occurrences, two examples from the *Rhynchonella cuvieri*-zone of Dover, and one from the same horizon at White Nothe, Dorset.

Hemiaster minimus† Agas., is perhaps not a good zonal fossil, as it extends, in diminishing numbers, as high as the zone of *Micraster cor-testudinarium*. It reaches, however, its maximum of numerical strength in this zone, being commoner in Devon than at Dover.

Echinoconus castanea in Devon is singularly local in its horizontal distribution. We did not find it at Pinhay or Whitlands, and it only begins to be at all common when we reach Beer Harbour. It is in the Hooken, however, and principally on Hooken Beach, that we find this urchin in profusion. We collected 30 here in one day, no less than 13 of which were contained in one block. Its vertical range is not so restricted as at Dover; but it must be remembered that in sections where we find it abundantly the zone has been condensed from 60 to 20 ft. in thickness. At Dover, on the other hand, we can only hope to find it in any number in the lower part of the zone, especially in the "Grit-bed," though we shall show (p. 40) that it has a higher vertical distribution than is usually known.

Salenia granulosa is probably commoner at Dover than on the Devon coast, and though it ranges through the White Chalk, as high as the zone of *Actinocamax quadratus*, it is generally regarded as a useful guide-fossil in this zone.

Glyphocyphus radiatus is never common in any locality, but it is one of the most useful of guide-fossils, as it is practically restricted to this zone. We have a single example from the *Terebratulina gracilis*-beds at White Cliff, and this is the only instance in which we have ever found it beyond the limits of its own horizon.

* See *Holaster cretaceus*, Sorignet. Oursins foss. Eure, 1850, p. 69, No. .
† M. Jules Lambert tells us that the correct designation of this species is *Peroniaster (Hemiaster) nasutulus*, Sorignet.

Cidaris hirudo, though always a common fossil in the White Chalk, reaches in Devon an abundance which is quite without parallel in England. From White Cliff to Hooken Beach we not infrequently find complete, but spineless, tests of this urchin. We are, however, entirely dependant on weathering to expose these fossils, for the rock is so hard that we can never hope to develop them.

Ammonites (*Pachydiscus*) *peramplus* is fairly common in this bed, perhaps to about the same extent as we find it in Sussex, but never approaching the numbers found at Dover. We also find *Ammonites cunningtoni*, both at Dover and in the landslip, but *Ammonites catinus*, recorded for Dover, was not seen on this coast.

Serpula avita, Sby., the type of which may be seen in the Sowerby Collection in the British Museum (Natural History), Cromwell Road, is worthy of mention. On p. 44 of the Dorset paper we state that a *Serpula* living in colonies has been found by us in Kent, Sussex and Dorset, on the shell of *Inoceramus mytiloides*. We have not found it on any other shell, nor in any other zone. It is, therefore, not only a useful guide-fossil, but an interesting example of constancy in choice of habitat.

So much, then, for the guide-fossils. It will be interesting to compare the associated guide-fossils in the same way.

It seems strange to degrade *Echinoconus subrotundus* to the position of an associated guide-fossil only, but we take the facts as we find them, and record that we collected only two examples on this coast in the zone with which we are dealing. At Dover, on the other hand, the species is not only abundant, but often of large size. We know of no coast-section where the true subrotundate form, with narrow base, is so well shown as at Dover.

Cyphosoma radiatum is abundant, and may reach a large size in this zone, a fact which is not commonly recognised. We have an example from Dover measuring 30 mm. in diameter, and General Cockburn has one of equal dimensions.

Pentacrinus of small size is usually common at this horizon in Devon, and it occurs at Dover. It is interesting to note that the columnars increase in size as we ascend the zones, reaching their maximum, both in size and number, in the zone of *Holaster planus*. We see the same progressive increase in size in the columnars of *Bourgueticrinus* up to the zone of *Micraster cor-anguinum*, beyond which point there is as a rule a decrease. For zonal peculiarities in this crinoid the reader is referred to the Kent and Sussex paper.

Terebratula semiglobosa and *Terebratulina carnea* are usually common and of considerable size in this zone. Here, as at Dover, we find the var. *albensis* well represented. We pointed out this occurrence on p. 319 of the Kent and Sussex paper.

Ostrea vesicularis, which, as Hébert said, has nothing peculiar about it, save that it is found throughout the chalk, hardly appeals

to one at first sight as being a likely fossil for zonal purposes. It is abundant both in Devon and at Dover, and found in every other exposure of this zone which we have examined, and always in one form. The attached valve is small, flat, and circular, with evenly up-turned edges. It usually weathers out as a white object against the grey marly matrix, and is thus readily seen.

Among the most interesting fossils, other than those set apart as zonal guides, is *Micraster*. For many years it has been known that *Micraster* occurred in this zone in Devon, thus giving a lower record than that of any other exposure of the same age in England. Our knowledge of the distribution of this genus in the zone of *Rhynchonella cuvieri* was summarised up to 1899 in "An Analysis of *Micraster*,"* and Mr. Meÿer, whose careful work on the Devon coast is to be found in a paper entitled "The Cretaceous Rocks of Beer Head,"† was probably the first to collect the urchin in this locality. His collection is now in the Woodwardian Museum, Cambridge, and we have had the opportunity of seeing all his local examples of *Micraster cor-bovis* and *Micraster leskei* from the zones of *Terebratulina gracilis* and *Rhynchonella cuvieri*. Adding our own specimens to his we see clearly that both these echinids occur in the *Rhynchonella cuvieri*-zone, and that *Micraster cor-bovis* is the more common form. The average length of our own examples is 32 mm. We mention in the Kent and Sussex paper, p. 316, that General Cockburn has found two examples of *Micraster cor-bovis* at the extreme base of the *Terebratulina gracilis*-zone in the Lydden zigzag at Dover. This is the only exact record for the lowest occurrence of this urchin in Kent, for our own examples were obtained from fallen masses in the West Cliffs. In the Museum of Practical Geology, Jermyn Street, is an example of *Micraster leskei* (Rh. 4547), from the *Rhynchonella cuvieri*-zone of Beer Harbour; and in the Mëyer collection, Woodwardian Museum, another from the same zone of Lulworth Cove, Dorset.

Holaster planus and *Holaster placenta* have been found in this zone at Dover, but not in Devon, and the same remark applies to *Cidaris serrifera*. They are all notably rare occurences.

Cidaris clavigera, Kœnig, is one of the interesting fossils peculiar to this section. In 1856, Desor‡ described a spine, under the title of *Cidaris sorigneti*, which he considered to be different to those of *Cidaris clavigera*, and described as "a radiole of the type of *Cidaris clavigera*, Kœnig, with which it has often been confounded, but with shorter stem and more pointed spines." The test was unknown. A reference to the same species is also found in Cotteau,§ who refers to the test as unknown. We have had the good fortune to

* *Quart. Journ. Geol. Soc.*, vol. lv, pp. 524, 529, 543, Aug., 1899.
† C. J. A. Meÿer, *Quart. Journ. Geol. Soc.*, Aug. 1874.
‡ *Synopse des Échin. foss.*, Tab. vi, fig. 16, p. 446 (Ed. 1858).
§ *Pal. franç.*, *Ter. Crét.*, t. vii, 1862-1867, p. 237, Pl. 1051, figs. 9-14.

find six tests, or segments of tests, of a beautiful cidarite with imperforate mammillon, one of which has a spine on the same block of chalk. This test exactly conforms to the figures of *Cidaris clavigera*, so that here we have a zonal variation of great variety and interest, affecting the spines only. Whether the spines found in Devon are identical with those figured by Desor we are unable to say, as we have not seen the original specimens. In none of our coast-sections have we found *Cidaris clavigera* in this zone. One of the objects of our visit to Dover was to ascertain if the radiole of this cidarite, either in its short or spiny variety, or in its long and spineless form, was to be found there. We searched for it without result. On the Devon coast we have not found this spine east of Connett's Hole, where it is rare, but it is more common at Beer Harbour and Hooken Beach, and becomes very abundant at Branscombe.

We found a single example of *Antedon* at White Cliff. As far as we know this is the lowest recorded horizon in the White Chalk for this rare fossil.

Rhynchonella plicatilis was found at Dover only, and is a notably low occurrence; while a still rarer record is that of *Kingena lima* from the same locality. *Terebratulina gracilis* we found in both counties in this zone, but it is decidedly rare. An interesting fact is that it is not smaller than the examples of ordinary size in its own zone.

The oysters found on this coast are *Ostrea vesicularis* and *Ostrea hippopodium*, Dover yielding in addition *Ostrea acutirostris* and *Ostrea normaniana*, all being of small size. We have not recorded *Plicatula barroisi* in this zone before, where it is found both in Devon and Kent, though rare in both instances. It increases in numbers up to the zone of *Holaster planus*, and then gradually diminishes. We have no record of it above the *Marsupites*-zone at present. *Spondylus latus* and *Spondylus dutempleanus* are found on both coasts, both being notably small, and the latter new to our list. *Spondylus latus*, var. *æquicostatus*, Eth., is also a new record, and found by us in Devon only.

Teredo amphisbæna is found in both localities, though whether it is the same species as that found in higher zones is questionable. *Radiolites* was only found at Dover.

Our record of vertebrates consists in both counties of the teeth of *Scapanorhynchus subulatus*, *Corax falcatus*, *Lamna appendiculata*, *Oxyrhina mantelli*, and *Ptychodus mammilaris*, with the addition of *Ptychodus polygyrus* at Dover.

Among the cephalopods and gasteropods not already mentioned we may record *Pleurotomaria*, which is common to both counties, and *Baculites baculoides* (?), *Crioceras*, sp., and *Nautilus sublævigatus* (?) in Devon alone.

The sponges are much richer at Dover, but among the rarer forms we record *Tremabolites* cf. *perforatus* as being found in

Devon only, whereas *Cephalites*, *Guettardia*, and *Craticularia*, so abundant at Dover, are here poorly represented. *Porosphæra globularis* is very small in this zone, and gradually increases in size until the *Marsupites*-zone, after which it again diminishes.

The corals are not without interest, as *Parasmilia centralis* and *Onchotrochus serpentinus* are found in both counties, the latter being a new record; while *Parasmilia monilis* was obtained at Dover alone. From the latter locality we collected two corals, which apparently belong to the genus *Podoseris*, and do not seem to have been described. In this zone *Parasmilia* is curious in that, though evidently of full growth, all examples found are remarkably small.

We must now consider the bastard *Rhynchonella cuvieri*-fauna found at Branscombe, and already partly indicated on p. 25. To do this effectively we must print the guide-fossils in two parallel columns. It will be seen that the dominant fossils are derived from Echinoderma alone, *Inoceramus mytiloides* being entirely omitted, and *Rhynchonella cuvieri* appearing only as an associated guide-fossil. Had the normal and bastard exposures of this chalk occurred in widely separated areas this lack of faunal continuity would not have been so remarkable; but when we consider that they are separated by a distance of but one and a-half miles, we cannot fail to be impressed by the wonderful divergence of the fauna—a divergence which is only equalled by the lithological differences in the two series of beds.

Zone of Rhynchonella cuvieri (Branscombe and Berry Cliff).

[The beds of *Cidaris hirudo* and *Cidaris clavigera*.]

FLINTLESS CHALK. 20 ft.	FLINTY CHALK. 60 ft.
Cidaris hirudo C.	*Cidaris hirudo* C.
Cidaris clavigera C.	*Cidaris clavigera* C.
Discoidea dixoni R.C.	*Discoidea dixoni* R.C.
Cardiaster pygmæus R.C.	*Cardiaster pygmæus* R.R.
Hemiaster minimus R.R.	*Hemiaster minimus* R.
Echinoconus subrotundus R.	*Echinoconus subrotundus* R.
Pentacrinus C.	*Pentacrinus* C.

Associated guide-fossils common to both flinty and flintless beds in the Branscombe area.

Rhynchonella cuvieri R.	*Rhynchonella cuvieri* R.
Ostrea vesicularis R.	*Ostrea vesicularis* R.
Inoceramus lamarcki R.C.	*Inoceramus lamarcki* R.

Except that these beds are the Branscombe representatives of the normally developed zone of *Rhynchonella cuvieri*, they might

with equal propriety be designated the beds of *Cidaris hirudo* and *Cidaris clavigera*, for the rock is full of the spines of these beautiful urchins, and segments of tests, and even portions of the "lantern," are by no means uncommon.

Discoidea dixoni, *Cardiaster pygmæus*, and *Hemiaster minimus* need no special description, as the frequency of their occurrence is indicated in the table. It is a remarkable fact that *Echinoconus subrotundus* is found here in the same numerical proportion as in the normal chalk of this zone, while *Echinoconus castanea*, so common on Hooken Beach, only one and a-half miles away, is not represented by a single example. The small columnars of *Pentacrinus* are found in bands in the flintless chalk, and in the base of the flinty chalk. Such a wealth of encrinital remains is quite outside our previous experience.

The proportion found of *Rhynchonella cuvieri* and *Ostrea vesicularis* is so small that we could not place them in the list of guide-fossils. As *Inoceramus mytiloides* was not found it would hardly be likely that *Serpula avita* should occur, and such is indeed the case. *Inoceramus lamarcki*, however, in a measure takes the place of the usually constant *Inoceramus mytiloides*, but is never a common fossil.

One example of *Cardiaster cretaceus*, two of *Salenia granulosa*, and three of *Glyphocyphus radiatus* were found in the flintless chalk of the bed, but not in the flinty area; while one example of *Micraster cor-bovis* and one of *Cyphosoma radiatum* were yielded by the flinty division alone.

An occurence of interest was that of *Antedon* in the flintless chalk. We have shown the specimen to Dr. Bather, who does not recognise it as a described species.

It is unusual in coast sections to be able to announce any interesting fact about Asteroidea, but we are able to chronicle the fact that the flinty chalk has yielded several of the ultimate supero-marginal plate of *Metopaster cornutus*, Sladen. Mr. Jukes-Browne was the first to find these plates and to establish their identity. In Sladen's memoir* we learn that the specimen from which Wright's undescribed figure was drawn is no longer in existence, and that its derivation is equally unknown. We have to thank Mr. Jukes-Browne for investing this otherwise barren plate with living interest, for we now know of one zone and one locality in which this asteroid existed. The columnars of *Bourgueticrinus* are rare, but occur in both beds.

We did not find *Ammonites* or *Nautilus*, but record a well-preserved rhyncholith from the flintless beds. A cast of *Aporrhais* was found in the flintless chalk.

Among the brachiopods we find that one example of *Terebratula semiglobosa* var. *albensis* occurred in the flintless chalk, and two of the ordinary form in the flinty beds; that *Terebratulina striata*

* Cret. Asteroidea II (2) (*Pal. Soc.*), p. 55, Pl. xiv, Fig. 5 a, b, c, d.

was seen in both; and that a single example of *Terebratulina gracilis* was yielded by the flintless chalk alone. The complete absence of the last-named fossil is sufficient evidence to prove that these flinty beds, which so closely resemble those of *Terebratulina gracilis* in lithological characters, in reality have no connection whatever with that zone.

The only lamellibranch not already mentioned is a solitary specimen of *Spondylus latus* from the flintless beds.

The corals are represented by a dwarfed example of *Parasmilia centralis*, and one of *Epiphaxum auloporoides*, both from the flintless chalk, the latter being a new record for this zone in our experience; while a small *Diblasus* occurred in the flinty portion of the zone. The latter must be an unique record for an always scarce fossil.

Scapanorhynchus subulatus, *Lamna appendiculata*, and *Oxyrhina mantelli*, one example of each, are our only vertebrates.

Serpula is represented by a single specimen of *Serpula ampullacea*, which we do not remember to have found so low before.

Zone of Terebratulina gracilis.

Terebratulina gracilis		
Micraster cor-bovis		Beer Harbour 89ft.
Holaster planus	throughout the zone.	
Hemiaster minimus		
Discoidea dixoni		The Hooken 156¼ ft.
Echinoconus subrotundus		

Other characteristic fossils are: *Cyphosoma radiatum*, *Cardiaster cretaceus*, *Cidaris hirudo*, *Pentacrinus*, *Rhynchonella cuvieri*, *Inoceramus lamarcki*, *Spondylus spinosus*, and *Ammonites peramplus*.

We know of no section where *Terebratulina gracilis* is found in such profusion, or in so good a state of preservation; nor have we ever seen it reach a larger size. As we have shown on p. 15 the name-fossil sets in in abundance within 2 ft. of the first flint-line, all along the coast, so that we have no hesitation in adopting this feature as the base-line to the zone. That we find difficulty in seeing this fossil in the East Cliffs of Dover is not wonderful when we remember how wave-battered they are. In the fallen air-weathered masses in the Western Cliff it is more common, but it never rivals the richness of the Devon Coast.

Micraster cor-bovis is found in fair abundance from base to top of the zone, being especially common in the upper part. As at Dover, where it is rather less common, it never reaches the size of the giant forms found occasionally in the zone of *Holaster planus*. Passage-forms between *Micraster cor-bovis* and *Micraster leskei*

are seen at the top of the zone, but we have not yet succeeded in collecting *Micraster leskei*, though at Dover we have two examples of the latter from the upper limit of the bed.

Holaster planus is even commoner in this zone than we formerly stated. In Devon we have found it at the extreme base of the zone, and it increases in frequency as we ascend. The range at Dover is even lower, for we have obtained it in the upper part of the *Rhynchonella cuvieri*-zone, associated with *Holaster placenta*. The latter urchin we have not as yet found in the *Terebratulina gracilis*-zone of Devon, while at Dover it is quite common at its upper part, and of large size.

Hemiaster minimus and *Discoidea dixoni* are commoner in Devon than at Dover, and reach a larger size. The latter, indeed, is almost as abundant as in the *Rhynchonella cuvieri*-zone.

Until lately we had no idea how common *Echinoconus subrotundus* is in this zone at Dover, where it ranges up above the middle of the zone. By comparison, it is rare in Devon, and such examples as we have seen were obtained at the base of the bed. In all cases the average size is less than that of the full-grown examples in the zone below, and the base of the test is notably broader and flatter. It came to us as a surprise when we collected forms closely resembling *Echinoconus castanea* from this zone, one in Devon, and three at Dover.

Cidaris hirudo, *Cyphosoma radiatum*, and *Pentacrinus* are rather common in both counties; while *Cardiaster cretaceus* is recorded for Devon alone, where we collected eight examples.

Among the brachiopods we notice that *Rhynchonella cuvieri* is almost as common as in its own zone in both counties; that *Rhynchonella reedensis* and *Crania egnabergensis* make their first appearance in this zone in both districts; and that *Rhynchonella plicatilis* and *Rhynchonella woodwardi* are recorded for Dover alone.

In the case of the lamellibranchs we record *Inoceramus mytiloides*, *Inoceramus lamarcki*, and *Inoceramus cuvieri* in both sections, with the addition of *Inoceramus brongniarti* at Dover. In this zone *Spondylus* assumes much greater importance, *Spondylus spinosus* making its first appearance, and being notably small and flat, and *Spondylus latus* and *Spondylus dutempleanus* both becoming larger and more numerous. *Neithea quinque-costata* also now makes its first appearance, and *Plicatula barroisi* is markedly commoner than in the zone below. These remarks hold for both counties. Moreover, *Ostrea* now begins to differentiate and to become fairly common. We record *Ostrea vesicularis*, *O. hippopodium*, *O. semiplana*, *O. normaniana*, and *O. lateralis* in both sections. *Pecten cretosus* was found at Dover, and *Pecten pexatus*, Woods, at the top of the zone in Devon.

Teredo amphisbœna was not recorded in Devon, but at Dover

it is found in huge masses, sometimes over a foot long. There is a mass in the Museum of Practical Geology which clearly comes from this horizon.

Pleurotomaria perspectiva occurs in both sections, and *Turbo gemmatus* and *Aporrhais* at Dover alone. All are rare fossils.

Ammonites peramplus is by no means uncommon in Devon, one example being found at the top of the zone; but it is rare at Dover. *Nautilus* cf. *sublævigatus* was obtained in Devon only.

The corals are represented by *Parasmilia centralis* and *Onchotrochus serpentinus* in both counties, the latter being always rare, and the former rather common in Devon, and still of a dwarfed form.

Serpula is not an abundant fossil, but we have *Serpula granulata*, *S. plana*, *S. ampullacea*, and *S. fluctuata* common to both coasts, *S. macropus* recorded in Devon only, and *S. gordialis*, *S. ilium*, and *S. plexus* in Kent alone. The last is a decidedly low occurrence. In addition there is a long, thin, granulate tubular form which we collected at Dover, and two examples of a small spiral form on columnars of *Bourgueticrinus* from the Hooken. Neither of these have we been able to name.

In this zone in Devon we see *Haplophragmium* in vast numbers and of large size, sometimes as many as 5 or 6 being crowded on an inch of chalk.

Among the rarities in this zone we record *Ophiura* in both sections, an example of *Glyphocyphus radiatus* and *Arthraster dixoni* in Devon, and spines of *Cidaris serrifera*, *C. clavigera*, and *C. perornata* at Dover.

The vertebrates consist of teeth of *Lamna appendiculata*, *Oxyrhina mantelli*, and *Scapanorhynchus subulatus* in both localities, with the addition of *Ptychodus mammillaris* and *Ptychodus polygyrus* at Dover.

Sponges are as poorly represented in Devon as they are rich at Dover, and offer no special point for comment, save that *Craticularia* and *Guettardia* are no guide to horizon in Devon.

Zone of Holaster planus.

Holaster planus *Micraster præcursor* } of the group-form associated with this zone. *Micraster cor-bovis* *Micraster leskei*	Pinhay Cliff $39\frac{1}{2}$ ft.
Echinocorys vulgaris var. *gibbus* *Pentacrinus* *Cidaris serrifera* *Pleurotomaria perspectiva* *Turbo gemmatus*	Annis Knob, Beer Harbour 60 ft.

Other characteristic fossils are: *Cardiaster Cotteaui*, *Holaster placenta*, *Terebratula semiglobosa*, *Terebratula carnea*, *Rhynchonella plicatilis*, *Rhynchonella reedensis*, *Plicatula barroisi*, *Inoceramus brongniarti*, *Serpula ilium*, and *Eschara acis*.

Holaster planus is very abundant, and we know of no section of this zone where it is more uniformly distributed. Just as we would select Annis' Knob as an example of air-weathered nodular chalk, so would we choose it to demonstrate an abundance of this species. The surface is literally ringed with the thin-shelled markings of this urchin in section. We have shown that it is fairly common in the *Terebratulina gracilis*-beds (p. 40); but there is no comparison between the numerical strength in the two zones. As in all other sections, it is rigidly confined to the upper limit of its own zone. *Holaster placenta* is a rarer form here than at Dover.

Micraster præcursor is also abundant, and we have not seen a single example in either county below the lower limit of this zone. In shape-variations and essential features of the test this group-form conforms in every detail to the considerations set forth in "An Analysis of *Micraster*," pp. 533-4.* This is the only section in which we have found so few broad examples of this urchin known as *Micraster cor-testudinarium*, for here, indeed, we have collected only a solitary specimen. At Dover they are not uncommon, but they are rarer in Sussex and Dorset, where, it must be allowed, the exposures of this zone are very inadequate. On account of its local rarity we have been compelled to leave it out of the table of guide-fossils, and to give it a position of comparatively trivial importance.

Micraster cor-bovis is probably no more common here than in the zone of *Terebratulina gracilis*, and the same remark, though in a less degree, holds good for Dover. On the other hand, we found none of the giant forms which we have recorded in the latter section, where it reaches 80 mm. in length.

As at Dover, *Micraster leskei* is a really common form, and is, with the exception of the two examples mentioned on p. 40, rigidly confined within its zonal limits. It conforms in every particular to the definitions laid down in "An Analysis of *Micraster*," *Quart. Journ. Geol. Soc.*, lv, 1899, pp. 525—8.

Echinocorys vulgaris var. *gibbus*, on the other hand, is almost rare here, and is far more abundant at Dover. It is somewhat difficult to obtain perfect examples in the limited Devon sections, but the shape variations seem to be uniform with those collected in other exposures of this zone.

Pentacrinus is of large size and abundant, as at Dover, and is very rare above the upper limit of the zone. Among the Cidarites the spines of *Cidaris serrifera* are the dominant forms, and have associated with them those of *Cidaris hirudo*, *C. clavigera*, and

* *Quart. Journ. Geol. Soc.*, vol. lv, 1899.

C. perornata. These also are found at Dover, where we note *Cidaris sceptrifera* as well. *Cidaris perornata* is a rare spine below the level of the *Micraster cor-anguinum*-zone, where it is so characteristic as to be a guide-fossil.

Pleurotomaria perspectiva and *Turbo gemmatus*, two examples of each species, are recorded for Devon, but they are much commoner at Dover, where, in addition, both species are found in the zone of *Micraster cor-testudinarium.* They are, however, quite characteristic of the zone with which we are dealing, and have been yielded by it in every section along the coast. They do not, however, constitute the presence of the Chalk Rock in its zoological sense.

Cardiaster cotteaui, of a large and gibbous form, is found both here and at Dover, differing from the smaller, more elongated, and depressed form which we associate with the zone of *Micraster cor-testudinarium.* General Cockburn, of Dover, has the best collection of this interesting urchin with which we are acquainted.

Terebratula semiglobosa, *Terebratula carnea*, and *Rhynchonella plicatilis* are all abundant, as at Dover, though they do not perhaps reach the large size which is seen in that rich section, where some of the bigger forms rival the dimensions of *Terebratula carnea* of the Norwich Chalk. For a reference to the Dover section, see Kent and Sussex, *Proc. Geol. Assoc.*, xvi (6), 1900, p. 313.

Rhynchonella cuvieri is represented by a single example, and is also rare at Dover. *Rhynchonella reedensis*, on the other hand, as at Dover, now replaces it, and becomes comparatively common. *Crania egnabergensis*, so common at Dover, was not obtained here. *Terebratulina gracilis*, as in all other sections, is found in small numbers at the base of this zone, and then finally disappears.

Plicatula barroisi is rarer than at Dover, and the same remark applies to *Inoceramus brongniarti*; while the *Inoceramus* sp., mentioned on p. 314 of the Kent and Sussex paper, and figured by Mr. Woods in his work on the Chalk Rock,* was represented by a single example.

Spondylus spinosus is abundant, but still notably small, and generally with flattened valves, while *Spondylus latus* and *Spondylus dutempleanus* are larger, though not more numerous, than in the zone immediately below. These considerations apply to both counties.

Ostrea is poorly represented here by *Ostrea vesicularis*, *O. semiplana* and *O. hippopodium*, whereas at Dover we find *O. normaniana*, and *O. lateralis* in addition.

Sponges are not so rich as at Dover; and though we get the same hard iron-oxide casts of *Ventriculites impressus* and *V. mammillaris*, which are so common in all sections of this bed as to be fully characteristic, we miss *Camerospongia* and *Tremabolites*, which form an interesting occurrence at Dover.

* Henry Woods, "The Mollusca of the Chalk Rock," *Quart. Journ. Geol. Soc.*, vol. liii, May, 1897, Pl. xxvii, fig. 18, 19.

Serpula ilium, as at Dover, now comes in strongly, but it forms our solitary record for this coast; whereas at Dover we record *S. ampullacea*, *S. fluctuata*, *S. gordialis*, *S. granulata*, *S. macropus*, *S. plana*, and *S. plexus*, the latter being rare. We entirely miss the beautiful and lavish fauna of Bryozoa, so characteristic of Dover, though *Eschara acis* is fairly represented here.

Lamna appendiculata is our solitary representative of Vertebrata, though Dover furnishes us with *Corax falcatus*, *Scapanorhynchus subulatus*, *Oxyrhina mantelli*, *Ptychodus polygyrus* and *P. mammillaris*.

Zone of Micraster cor-testudinarium.

Owing to the scanty sections of this zone, which can only be worked at Pinhay Cliff, Annis' Knob, and in the cleft on Beer Head, our lists of fossils are of necessity incomplete.

Micraster præcursor	of the group form associated with this zone	throughout the zone.
Echinocorys vulgaris var. *gibbus*		
Holaster placenta		50 ft. exposed at Pinhay Cliff.
Cidaris serrifera		

Other characteristic fossils are: *Cardiaster Cotteaui*, *Rhynchonella reedensis*, *Plicatula barroisi*, and *Serpula ilium*.

Micraster præcursor is abundant, and conforms to all the details of the essential features of the test which regulate *Micraster* in this zone (see "An Analysis of *Micraster*," *Quart. Journ. Geol. Soc.*, lv, 1899, p. 533, 4). In this bed, more perhaps than in that of *Holaster planus*, we notice that *Micraster* has what we may term a geographical zonal facies in addition to the purely zonal characteristics. Those from Dover and Devon closely correspond, and differ perceptibly from the examples from the same horizon on the Dorset and Sussex coasts. These differences would only be appreciated by those who handle the group in large numbers, and in no way militate against the unity of the zonal types.

Micraster cor-testudinarium is so rare here, being represented but by two examples, that we have had to adopt the unusual course of degrading the name-fossil to the humble position of a zonal rarity. In all other sections it is quite an important feature of the zone —even the small and comparatively unfossiliferous exposure at Durdle Cove, Dorset, yielding a considerable proportion of broad forms.

Echinocorys vulgaris var. *gibbus* is almost a rare fossil, and contrasts strongly in this particular with the same species at Dover. It will be remembered that it is practically confined to a narrow band at Pinhay Cliff (p. 5), so that our chances of collecting perfect examples are but few. One notable feature of this urchin, as here imperfectly displayed, is the remarkable narrowing of the

base, which is so marked in some specimens as to remind one of extreme examples of *Echinoconus subrotundus*.

At Dover we mention (Kent and Sussex, p. 309) the abundance and large size of *Holaster placenta*. Here the size is much the same, but the number smaller. The spines of *Cidaris serrifera* are here still the dominant type, but are associated with *C. sceptrifera* and *C. clavigera*; while at Dover we have in addition those of *C. hirudo*, and *C. perornata*. It is in this zone that *C. sceptrifera* begins to have some numerical strength, though it only becomes really common when we reach the zone of *Micraster cor-anguinum*.

Cardiaster cotteaui, which is represented by one example from the cleft at the top of Beer Head, does not correspond with the elongated and depressed type in this zone at Dover, but more with the larger and more elevated form found in the zone of *Holaster planus*. This is in no way remarkable when we consider that the cleft is cut in the base of the zone now under consideration.

Rhynchonella reedensis and *Plicatula barroisi* are common here, though not to the extent that is seen at Dover, and the same remark applies to *Serpula ilium*. As at Dover, *Terebratula semiglobosa*, *Terebratula carnea*, *Rhynchonella plicatilis*, and *Crania egnabergensis* become comparatively unimportant. On p. 310 of the Kent and Sussex paper we have mentioned the occurrence of *Rhynchonella limbata* in this zone. The occurrence is in the last degree unusual; but a recent visit only served to strengthen our original view, for we found it in an abundance, even below the middle of the zone, only to be equalled by that of the var. *lentiformis* in the zone of *Belemnitella mucronata*.

Among the lamellibranchs *Spondylus spinosus* is abundant, and is larger and with more inflated valves than in the zone below. *Ostrea* is poorly represented here by *O. vesicularis*, *O. normaniana*, and *O. lateralis*; whereas we have in addition *O. hippopodium*, and *O. semiplana* at Dover.

Serpula ilium is here fairly abundant, being associated with *S. granulata*, *S. ampullacea*, and *S. plexus*, while Dover yields in addition *S. fluctuata*, *S. gordialis*, *S. macropus*, and *S. plana*.

The vertebrates are here meagrely illustrated by a single tooth of *Ptychodus mammillaris*, but the same zone at Dover supplied us with examples of *Enchodus lewesiensis*, *Corax falcatus*, *Scapanorhynchus subulatus*, *Notidanus microdon*, and *Ptychodus polygyrus*.

The Bryozoa also afford but a poor list, and form a marked contrast to the exuberance of these beautiful forms at Dover. We have recorded, however, an example of rotiform bryozoan from the cleft on the top of Beer Head (p. 19). Among the rare fossils which we mention in this zone is an example of *Nautilus* cf. *atlas* from Pinhay (p. 4).

SYNOPSIS OF ZONAL MEASUREMENTS.

It is felt that in this coast of ever-varying zonal measurements the convenience of the reader would best be studied by giving these measurements in tabular form, so that the eye can at once trace the remarkable variations in thickness as we pass along the section from east to west. Those who wish to study the measurements in greater detail are referred to the geographical headings in the table of contents on p. 1, where each section is taken in its proper order. Several other measurements are given, which do not appear in this table, but, as they necessitate greater description than can be printed in a tabular form, they are intentionally omitted.

	Pinhay Cliff, Main section	Pinhay Cleft.	Whitlands.	White Cliff.	Connett's Hole.	Beer Harbour, North side.	Beer Harbour, West side.	Pound's Pool Beach.	The Hooken, From talus near adit for Beer Stone.	The Hooken, East side, path to Hooken Beach.	The Hooken, From a fallen mass.	Branscombe and Berry Cliffs.
Zone of *Micraster cor-testudinarium*	50 ft. exp.	...	...	...	...	30 ft. exp.	...	...	...	...	...	
Zone of *Holaster planus*	39½ ft.	...	...	...	...	60 ft.	...	...	...	...	...	
Zone of *Terebratulina gracilis* ...	37 ft. exp.	71½ ft.	30 ft. about	70 ft. about	...	89 ft.	...	...	...	156¼ ft.	...	35 ft. exp.
Zone of *Rhynchonella cuvieri* ...	...	59½ ft.	55 ft. about	28½ ft.	27½ ft.	25½ ft.	20 ft.	20 ft.	24 ft	16 ft.	14 ft.	60 ft. flinty ch. / 20 ft. flintless ch.

CORRELATION OF MR. C. J. A. MEŸER'S PAPER ON THE CRETACEOUS ROCKS OF BEER HEAD.

As far as we can judge from the lists of fossils which accompany the numbered beds, our zones correspond with the following numbers in Mr. Meÿer's excellent paper.

No. 20	= zone of *Holaster planus* and *Micraster cor-testudinarium*.
Nos. 18, 19	= zone of *Terebratulina gracilis*.
Nos. 14, 15, 16, 17	= zone of *Rhynchonella cuvieri*.

When we remember that this thoughtful and closely-reasoned paper appeared in 1874, two years before the issue of Barrois's great work, we see that an English amateur had got within measurable distance of the results obtained by the great French geologist. Useful as Meÿer's work is in the White Chalk, it appears to be far more valuable in the lower beds, to which, we believe, he devoted the greater part of his attention.

SHEETS OF THE 6-INCH MAPS EMPLOYED.

Pinhay to Rousden	Sheet 84
Rousden to Seaton and Beer Head	Sheet 83
Beer Head to Berry Cliff	Sheet 95

CONCLUSION.

Though this coast offers no difficulties of a physical nature, and every zone is readily accessible, there are certain zoological peculiarities which call for comment. These are mostly found in the zone of *Rhynchonella cuvieri*, which here introduces to our notice an unexampled wealth of Cidarite remains, including the unique variation in the spines of *Cidaris clavigera*; the first recorded appearance in England of *Cardiaster cretaceus*; the presence of *Micraster cor-bovis* and *Micraster leskei*; and the absence of the ever-constant *Inoceramus mytiloides* from the bastard fauna of Branscombe. Add to this the almost complete absence of the group-form of *Micraster cor-testudinarium* in the zones of *Holaster planus* and *Micraster cor-testudinarium*, and we have as instructive an instance of deviation from the normal as we need wish to see. To those who pin their faith to the lithological characters of a zone, and not to its fossils, we would instance the occurrence of an intensely flinty zone of *Terebratulina gracilis*, and an exposure of the *Rhynchonella cuvieri*-zone at Branscombe which has taken the unpardonable liberty of exhibiting belts of both flintless and flinty chalk.

Even at the risk of reiteration we would point out that

divergences from the normal such as these are just what we should expect to find, for though the dominant guide-fossils run true over a wide area, geographical variation must be reckoned with.

We have been at pains to make the key-plates as distinct and explanatory as possible, and to that end have included in them all the lithological features which we have recognised in the text as having zonal value. With these in hand it will be difficult for any worker in the field to fail to define the zonal boundaries with perfect ease.

Professor H. E. Armstrong has spared neither time nor pains to secure as perfect a series of photographs as possible, and has made several special journeys to Seaton for this purpose. We cannot thank him enough for the beautiful plates with which this paper has been embellished.

We have received invaluable assistance from M. Jules Lambert, Mr. Jukes-Browne, Mr. E. T. Newton, Dr. G. J. Hinde, Dr. A. Smith Woodward, Dr. F. A. Bather, Mr. G. C. Crick, Mr. Henry Woods, Dr. F. L. Kitchin, Dr. Blackmore, Mr. F. G. Collins, Mr. W. McPherson, and General Cockburn, and to each one we desire to express our gratitude for help so willingly given. To Professor Cullis and Mr. J. Allen Howe we are indebted for much help and forbearance in the publication of this paper, and to Mr. C. Davies Sherborn, above all, we would record our gratitude not only for his ever-ready help in the field, but for the admirable cliff-sections with which this work is illustrated.

LIST OF PLATES.

NOTES ON THE PLATES AND KEY-PLATES.

Abbreviations used.

M. ct. = Zone of *Micraster cor-testudinarium.*
H. p. = " " *Holaster planus.*
T. g. = " " *Terebratulina gracilis.*
R. c. = " " *Rhynchonella cuvieri.*
C. L. = Cenomanian Limestone.
G^{d}. = Greensand.

In all cases the extent of the main zonal exposures is indicated by a strong vertical line, and the zonal junction by a short line at right-angles to it. If a zone is incompletely exposed, either in an upward or downward direction, the short horizontal line is omitted. The names of the chief zonal exposures are indicated in thick type.

	Zone of *Rhynchonella cuvieri.*	Zone of *Terebratulina gracilis.*	Zone of *Holaster planus.*	Zone of *Micraster cor-testudinarium.*
Craticularia fittoni, Mant.	...	R.	...	...
Guettardia stellata, Mich.	...	R.	R.	...
Ventriculites cribrosus, Phill.	...	R.	R.	...
Ventriculites decurrens, T. Smith	...	R.R.	R.	R.
Ventriculites impressus, T. Smith	R.	R.R.	C.	R.
Ventriculites mammillaris, T. Smith	R.	R.	C.	...
Ventriculites radiatus, Mant.	...	R.C.	R.R.	R.R.
Cephalites benettiæ, Mant.	R.R.	R.	...	...
Plocoscyphia convoluta, T. Smith	R.	C.	C.	C.
Porosphæra globularis, Phill.	C.	C.	C.	C.
Porosphæra pileolus, Lam.	R.	R.R.	R.R.	R.
Tremabolites cf. *perforatus*, T. Smith	R.	...	...	...
Parasmilia centralis, Mant.	R.	R.C.	R.	...
Parasmilia fittoni, E. and H.	R.	...	...	...
Epiphaxum auloporoides, Lonsd.	R.	...	...	...
Diblasus sp.	R.	...	...	...
Onchotrochus serpentinus, Dunc.	R.	R.	...	...
Bourgueticrinus	R.R.	R.C.	R.C.	R.C.
Pentacrinus	C.	R.C.	C.	...
Antedon	R.	...	...	...
Asteroidea	C.	C.	C.	C.
Metopaster cornutus, Sladen	R.	...	...	...
Arthraster dixoni, Forbes	...	R.	...	...
Ophiura	...	R.	...	...
Cidaris sceptrifera, Mant.	...	...	...	R.C.
Cidaris clavigera, König	C.	R.	R.R.	R.C.
Cidaris perornata, Forbes	...	...	R	...
Cidaris hirudo, Sorig.	C.	R.C.	R.C.	...
Cidaris serrifera, Forbes	...	R.	C.	C.
Cyphosoma radiatum, Sorig.	R.C.	R.C.	R.C.	R.
Salenia granulosa, Forbes	R.	R.	R.	...
Glyphocyphus radiatus, Hoening	R.	R.	...	...
Echinocorys vulgaris, Breyn.	...	...	R.R.	R.R.
Echinoconus subrotundus, Mant.	R.	R.R.	...	...
Echinoconus castanea, Brongn.	C.	R.	...	...
Discoidea dixoni, Forbes	C.	C.	...	...
Micraster præcursor (group)	...	...	C.	C.
Micraster cor-testudinarium (group) Goldf. ...	...	...	R.	R.
Micraster leskei, Desm.	R.	...	C.	...
Micraster cor-bovis, Forbes	R.	R.C.	R.C.	...
Hemiaster minimus, Ag.	C	R.C.	R.	...
Holaster planus, Mant.	...	R.C.	C.	...
Holaster placenta, Ag.	...	...	R.C.	R.C.
Cardiaster cotteaui, d'Orb.	...	...	R.	R.

	Zone of *Rhynchonella cuvieri.*	Zone of *Terebratulina gracilis.*	Zone of *Holaster planus.*	Zone of *Micraster cor-testudinarium.*
Cardiaster pygmæus, Forbes	C.	...	...	...
Cardiaster cretaceus, Sorig.	C.	R.R.	...	...
Serpula ampullacea, Sby.	R.	R.	...	R.
Serpula avita, Sby.	C.	...	...	...
Serpula fluctuata, Sby.	...	R.	R.R.	R.R.
Serpula plana, S. Woodw.	R.	R.	R.	R.
Serpula granulata, Sby.	...	R.	...	R.
Serpula ilium, Sby.	...	...	C.	C.
Serpula macropus, Sby.	...	R.	...	...
Serpula sp.	...	R.	...	...
Crania egnabergensis, Retz.	...	R.	...	R.
Terebratulina striata, Dav.	R.R.	R.C.	R.R.	R.
Terebratulina gracilis, Schl.	R.	C.	R.	...
Terebratula semiglobosa, Sby.	C.	R.C.	C.	R.C.
Terebratula carnea, Sby.	R.R.	R.C.	C.	R.
Rhynchonella reedensis, Eth.	...	R.	R.C.	R.C.
Rhynchonella cuvieri, d'Orb.	C.	R.C.	R.	...
Rhynchonella plicatilis, Sby.	...	...	R.C.	R.
Pecten cretosus, Defr.	R.	...	...	...
Pecten pexatus, Woods	...	R.	...	...
Neithea quinquecostata, Sby.	...	R.	...	...
Spondylus spinosus, Sby.	...	C.	C.	R R.
Spondylus latus, Sby.	R.R.	R.C.	R.R.	R.
Spondylus latus var. *æquicostatus*, Eth. ...	R.	...	...	...
Spondylus dutempleanus, d'Orb.	R.R.	R.C.	R.R.	R.
Ostrea vesicularis, Lam.	C.	C.	R.	R.
Ostrea hippopodium, Nils.	R.	R.R.	R.	R.
Ostrea semiplana, Sby.	...	R.R.	R.	...
Ostrea normaniana, d'Orb.	...	R.	...	R.
Ostrea lateralis, Nils.	...	R.	...	R.
Plicatula sigillina, Woodw.	...	R.R.	R.R.	R.R.
Plicatula barroisi, Peron	R.	R.C.	R.C.	R.R.
Inoceramus cuvieri, Sby.	...	C.	R.R.	C.
Inoceramus mytiloides, Schlot.	C.	R.R.	...	...
Inoceramus lamarcki, Park.	R.C.	R.C.	...	...
Inoceramus brongniarti, Sby.	...	R.	R.R.	...
Inoceramus sp. *	...	...	R.	...
Teredo amphisbæna, Goldf.	R.R.	...	...	...
Pleurotomaria perspectiva, Mant.	R.	R.	R.	...
Turbo gemmatus, Sby.	...	...	R.	...
Aporrhais sp.	R.	...	...	...
Rhyncholites	R.	...	...	...
Nautilus cf. *sublævigatus*, d'Orb.	R.	R.	...	...
Nautilus cf. *atlas*, Whiteaves	...	...	...	R.

* *Quart. Journ. Geol. Soc.*, vol. liii, 1897, Woods, "Mollusca of Chalk-Rock," Pl. xxvii, Figs. 14, 15.

	Zone of *Rhynchonella cuvieri.*	Zone of *Terebratulina gracilis.*	Zone of *Holaster planus.*	Zone of *Micraster cor-testudinarium.*
Crioceras sp.	R.	...	...	...
Baculites (?) *baculoides* (Mant.)	R.	...	...	...
Ammonites cunningtoni, Sharpe	R.	...	...	...
Ammonites peramplus, Mant.	R.R.	R.C.	...	...
Scalpellum maximum, Sby.	...	R.	...	...
Scapanorhynchus subulatus, Ag.	R.	R.	...	...
Lamna appendiculata, Ag.	R.	R.	R.	...
Oxyrhina mantelli, Ag.	R.	R.	...	...
Corax falcatus, Ag.	R.	...	...	...
Ptychodus mammilaris, Ag.	R.	...	...	R.

ORDINARY MEETING.

Friday, December 5th, 1902.

H. W. Monckton, F.L.S., F.G.S., President, in the Chair.

The President referred to the loss sustained by the Association in the death of one of its founders, the Rev. Thomas Wiltshire, who was almost its first President, and who had always taken the greatest interest in the welfare of the Association.

The following were elected members of the Association: F. Bowles, James V. Elsden, B.Sc., F.G.S., Charles Force, Charles Fox-Strangways, F.G.S., James Guest, William Jerome Harrison, F.G.S., Mrs. R. S. Herries, Hugh Hunter, Herbert C. Male, M.D., A. G. Ruston, B.A., Lieut.-Col. G. L. Tupman, E. Percy Turner.

The following papers were then read: "On the Formation of Chert," by Miss Catherine A. Raisin, D.Sc., illustrated by lantern slides, and "A List of the Fish Remains from the Middle Bagshot Beds of the London Basin," by A. K. Coomáraswámy, B.Sc., F.G.S.

ORDINARY MEETING.

Friday, January 2nd, 1903.

H. W. Monckton, F.L.S., F.G.S., President, in the Chair.

The following were elected members of the Association: Henry Horace Crawley, Paul Mallon, Edgar Willett, M.A., M.B., F.R.C.S.

Dr. F. L. Kitchin and Mr. G. E. Dibley were elected Auditors.

An interesting lecture, entitled "A Visit to St. Vincent and Martinique," was then delivered by Mr. John S. Flett, M.A., D.Sc., F.R.S.E., the lecture being well illustrated by lantern slides.

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EDITED BY

J. ALLEN HOWE, B.Sc., F.G.S.

(Authors alone are responsible for the statements in their respective Papers.)

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(*Continued on page 3 of the Cover.*)

ON THE RECENT GEOLOGICAL HISTORY OF THE BERGEN DISTRICT OF NORWAY.

Being an Address delivered at the Annual General Meeting of the Geologists' Association, on March 6th, 1903.

By the President, HORACE WOOLLASTON MONCKTON, F.L.S., F.G.S.

MY predecessor in this chair has, in his addresses to you for the last two years, dealt so fully with recent geological work at home that I think possibly I may be doing well in seeking somewhat farther afield for the subject of my address to you this evening, and I consequently venture to ask you to follow me across the North Sea and explore some of the mountains and sea-lochs of southern Norway.

The district to which I wish to draw your attention is that around the great fjords of Sogne and Hardanger, and as both are included in the Amts or Counties, North and South Bergenhus, the whole may fairly be described as the Bergen District. I have already, in a lecture, drawn your attention to this district, and since I gave that lecture in January, 1898, I have paid three visits to it, and have added considerably to my notes on its geology and geography. I have also taken a large number of photographs, some of which I hope to show you this evening.

In recent years, too, the officers of the Geological Survey of Norway have published a good deal of imformation relating to the district in question, and I have made great use of their memoirs when in that country. More especially I desire to express my appreciation of the admirable work done by the Director of the Survey, Dr. Hans Reusch, and of the clear and interesting manner in which it is described in his published works.

Of course, I alone am responsible for the opinions which I venture to express in this address, but I wish it to be clearly understood that I am mainly indebted to Dr. Reusch and his colleagues for the ideas which have led to my conclusions.

The following are the works which I have found of more especial use in studying the district:

1. Forbes, J. D.—Norway and its Glaciers Visited in 1851. 8vo, Edinburgh, 1853.
2. Kjerulf, T.—Udsigt over det sydlige Norges geologi. 2 vols., Christiania, 1879. (Edition in German, Bonn, 1880.)
3. Sexe, S. A.—Mærker efter en Istid i omegnen af Hardangerfjorden. Christiania, 1866. (French translation.)
4. Sexe, S. A.—Boiumbræen. 4to, Christiania, 1869. (also in French.)

5. SEUE, C. de.—Le Névé de Justedal et ses Glaciers. Christiania, 1870.
6. HELLAND, A.—On the Ice-Fjords of North Greenland, and on the Formation of Fjords, Lakes, and Cirques in Norway and Greenland. *Quart. Journ. Geol. Soc.*, vol. xxxiii, p. 142 (1877).
7. REKSTAD, J.—Om periodiske forandringer hos norske bræer. Norges G. U., Aarbog, 1896-99.
8. REUSCH, HANS.—Nogle bidrag til forstaaelsen af hvorledes Norges dale og fjelde er blevne til. (Summary in English.) Norges G. U., Aarbog, 1900.
9. REUSCH, HANS.—Vore Dale og Fjelde. Naturen Bergen, 1902.

I have already touched on the subject of this address in the pages of the *Geological Magazine*, and I would refer to my two papers there for additional details as to some of the matters with which I propose to deal this evening. The papers to which I refer are: "Notes on Some Hardanger Lakes," *Geol. Mag.*, dec. iv., vol. vi, p. 426 (1899), and "Some Examples of Marine and Subaerial Erosion," vol. ix, p. 406 (1902).

I. INTRODUCTION.

The Bergen District of Norway is on the latitude of the Shetland Isles. The coast is fringed by a network of islands, and fjords or sea-lochs run far into the interior. Outside the islands the 100-fathom line keeps very close inshore, and beyond it the sea-bottom rapidly sinks into the great channel which runs along the coast of Norway from the Christiania Fjord to the Arctic Sea.

The origin of this channel has been a matter of much discussion. It may be a submerged river-valley, and the mere fact that its deepest part is at the Christiania Fjord end, inland so to say, is no objection to such a view, for this is the case in many fjords of both Norway and Scotland which are admitted to be or to have been river valleys. It is the existence of this great channel which led me to remark, when we were at Cromer the other day, that I do not believe any Norwegian land-ice has ever travelled to England as land-ice (*Proc. Geol. Assoc.*, vol. xvii, p. 486). If the Arctic Ocean down to the north of Scotland had been occupied by a polar ice-cap, glaciers might, I admit, have advanced from Norway to England, but the evidence before us is against the existence of such an ice-cap, even during the Glacial Period (J. Geikie, "The Great Ice Age," 2nd edit., 1877, p. 404), and in its absence the Norwegian ice would, it seems to me, have followed the great channel towards the Arctic Ocean.

It is true that many boulders which are almost certainly of Norwegian origin have been found in the Yorkshire Drifts, but they have probably travelled in two or more stages, a part of the transit having been effected by floating ice.

The solid rock of the district is very old. It consists of:

1. *Archæan.*—Gneiss, Gneiss-granite, etc.

2. *The Telemark Formation* (Pre-Cambrian). — Quartzites, conglomerate of quartzite pebbles, fine-grained gneiss, hornblende schists, altered igneous rocks.

3. *Cambro-Silurian.*—Micaceous schist, green schist with quartz eyes, dark blue quartzite, phyllite, occasional limestone and conglomerate. With this series are associated masses of igneous rock more or less altered.

Three stages have been distinguished in the process of reduction of the land surface to its present contours.

Firstly.—There are several plateaux, mostly now covered by perpetual snow, and also a few mountain tops. These have a tolerably uniform level of from 5,000 to 6,500 feet above the sea, and they are probably fragments of a very old land surface, which we may speak of as the *Oldest land.*

Secondly.—Probably owing either to the elevation of Norway or to the depression of the North Sea area, the various agents of subaerial erosion have carved out of this oldest land an undulating landscape with rounded hills and wide shallow valleys forming what Dr. Reusch has termed the *Palæic Surface* of the country (No. 8,* p. 133). It has an average level of some 3,000 feet.

Thirdly.—At some time, perhaps not very remote, a series of earth movements took place, resulting in elevation, and in consequence the rivers and streams deepened their channels and produced the narrow and deep valleys in which the fjords lie. These may be called the *Fjord-valleys*, and the term may conveniently be used whether the valley or part of the valley of which we happen to be speaking be below or above sea level, whether the bottom be covered by water or be dry land.

II.—THE HIGH PLATEAUX.

The most extensive remains of the oldest land surface are to be found north of the Sogne Fjord in the north-east part of the district (No 8, p. 132). They are almost covered by snow-fields, the largest of which is known as the Jostedalsbræ. On it the snow attains an elevation of 6,683 ft., and on the others the snow rises to between 5,000 and 6,000 ft. above the sea.

Crossing to the south of the Sogne Fjord there is the Fresvik Snow-field a little west of the Naerö Fjord, rising to a height of over 5,000 ft., and in the mountain tract between the Aurlands Fjord and the Lærdals Fjord we find the mountain Blejen (5,556 ft.), and the small snow-field Blaaskavl (5,813 ft.)

* The reference number refers to the list of works given above.

Storskavlen is another small snow-field about 7 miles south-east of the head of the Aurlands Fjord, with a level of 5,608 ft. Above the head of the Hardanger Fjord and 6 miles east of the landing stage in Simodal there is a nearly circular snow-field, Hardanger Jokul, which I believe attains a level of about 6,000 ft., and 16 miles east of the Sör Fjord is Haarteigen, a solitary mountain 5,546 ft. high, with a square top easily recognisable from great distances; and on the west of the Sör Fjord and between it and the Hardanger Fjord is the great snow-field Folgefond, with a level of over 5,000 ft. Lastly, and in order to complete the list, perhaps I should mention Hallingskarven, though it is just outside the district on the east.

The rock of these plateaux is almost concealed by snow, but here and there a rock peak rises above the snow-field, or a knob of rock may be temporarily uncovered.

I examined one knob at a level of about 3,800 ft. on the Jostedal Snow-field. The rock was a gneiss. The corners were angular, but somewhat smooth and rounded. I could see no sign of striation, or ice-marking.

In 1901 I took some photographs on the Frudalsbræ, a small snow-field with a level of 5,200 ft. on the east of the Fjærlands Fjord. At the edge of the plateau the ground was free from snow, and was covered by a mass of broken fragments of rock. The rock appeared to be the rock of the locality, and the fragmentary state was no doubt due to frost. There was nothing of the nature of moraine about the fragments, and clearly no glacier had passed over this spot since they were broken from the rock. Indeed, probably no glacier ever has crossed this high plateau, and this fragmentary surface covering may have lain here since pre-Glacial times. No doubt the snow-field has rested upon it for ages, but I see no reason why a snow-field should leave any mark upon a flat surface. True, the lower part of the snow may become consolidated into ice, but it does not follow that the ice will move unless there be inequalities of surface.

A covering of broken fragments of rock is usually found at the highest levels in most districts. The summit of Ben Nevis in Scotland is a good example. The surface at its top is covered with broken angular fragments of the Hornblende Andesite which forms the upper part of the mountain.

It must not, however, be assumed that such a covering of rock fragments shows that the spot has not been traversed by ice during the Glacial Period. Sultind is a solitary knob of rock rising to a height of 5,803 feet, almost on the eastern watershed of the Sogne Fjord drainage area. The summit is covered with a great mass of broken rock fragments, but there is also close to its top a big block,* which has all the appearance of an erratic.

* This block was noticed long ago by Mr. Keilhau. J. C. Hörbye, *Obs. sur les Phénomènes d'érosion en Norvège*. Christiania. 4to. 1857, p. 10.

Probably ice at one time passed over Sultind, but at a later stage of the Glacial Period, when the ground around the mountain was covered with snow and ice, the knob of rock which forms the top remained exposed to the action of frost and the broken rock fragments are the result.

The snow of the snow-fields is mainly in the partially consolidated state known as névé, and in summer, when I have visited them, the surface has usually been fairly hard and easy to walk over. In 1901, however, the surface of considerable areas was in a soft and somewhat melted state. Seen from below or from a distance, these soft areas were more of the colour of ice than snow, and I expected to find that they were ice, but when I got on to a patch I found out my mistake, and on one day my guide twice turned and made a long circuit when he found the surface getting soft and wet.

In places the névé does get consolidated into ice, and the snow-fields are bordered with a fringe of glaciers.

Most of these glaciers are short, of considerable width, and more or less semicircular in shape. They are usually covered with longitudinal fissures arranged fan-wise.

A good example may be seen from the Fjærlands Fjord perched high up on the side of the Valley of Boium.

In other cases glaciers descend some distance into the valleys. Thus the Bjaastadbræ originates on a small snow-field also above the Fjærlands Fjord and flows down into a pass between the valley of the fjord and that of the Sogndals river, and the ice nearly reaches a little lake or tarn which lies just below the watershed on the Fjærlands side. There is a considerable area free from vegetation near and below the ice, and a moderate amount of moraine material lies around. I think that the lower end of the ice must be about 3,000 feet above the fjord. This glacier is easily visited from Mundal.

The Rembesdalsbræ above the head of the Hardanger Fjord is a more interesting but not so accessible example of the same type of glacier. It descends from the snow-field Hardanger Jökul. Its length is about two miles and its breadth at the lower end about a third of a mile. Its surface is covered with longitudinal fissures. The glacier descends into a lake and icebergs break off from its foot, and may be seen floating about the lake or stranded around its shore.

The lake is at a considerable height above the fjord, perhaps about 3,000 feet.

In other cases glaciers travel far below the snow-fields down into the fjord-valleys and nearly to sea level, and I will mention one or two of them after I have described some of the deep valleys themselves.

III.—THE PALÆIC SURFACE.

At some far distant time earth movements appear to have taken place, causing an increase of the erosive power of the streams and rivers, and the oldest land surface was in consequence to a great extent removed by denudation. In course of time a new land surface was carved out at a somewhat lower level than the oldest land, but though new as compared with what happened previously, it is old, very old indeed, as compared with what has since occurred, and Dr. Reusch has termed it the Palæic Surface of the country (No. 8, p. 133).

The erosive power of streams and rivers may be increased either by the elevation of the district over which they flow, or by the depression of an area between that district and the sea should such depression shorten the course of the rivers, and it is possible that the cutting away of the oldest land surface may have been due to the depression of the bed of the North Sea.

It may, on the other hand, have been the result of movements of elevation, and probably in effect there were many earth movements, and it may eventually be found possible to divide the Palæic surface into several stages, each the result of a separate series of earth movements. At present, however, that has not been attempted, and it is a matter of minor importance, so far as the Bergen District is concerned, for there the Palæic surface is well and clearly marked off both from the oldest land above it, and also from the newer surface, which will be dealt with in my next section. The date of the earth movements which gave rise to the Palæic Surface is uncertain. Probably we may say that they were post-Silurian and pre-Tertiary, but I doubt whether we can go nearer than that.

The Palæic Surface is characterised by rounded hills and wide shallow valleys, and with the exception of the plateaux and hill tops mentioned in the last section of this address, it includes the uplands of the district—more than half the whole area, in fact.

Travellers by the Valders Route from Christiania to the Sogne Fjord cross the Palæic Surface between Skogstad and Maristuen. It is an open moorland dotted over with tarns large and small, and with pasture for numerous cattle. Sultind, the mountain with the erratic block on its top, already mentioned, rises above the moor, and some thirty miles to the north we see the peaks of the Jotunheim Mountains. The rock is for the most part a hard gneiss and the surface has been worn and its contours rounded by ice. A great number of boulders, some of considerable size, lie scattered over it.

When I visited the place in the summer of 1898 there were many patches of snow down to levels of about 3,000 feet, but in July, 1901, I found there was no snow on the moor around

Sultind, though there were patches at higher levels towards the Jotunheim.

The river Læra rises near Sultind and flows down a wide valley to the Smedal Lake. Below the lake its bed gradually becomes steeper. Close to Maristuen it is joined by a tributary stream from the south-east, which comes down a wide, shallow valley. Around there is much moraine material, and the rock is ice-worn, but after passing Maristuen the Læra leaves the Palæic Surface and enters a series of steep ravines, the sides of which show but little sign of the former presence of ice.

There is a great extent of high land belonging to the Palæic Surface around the head of the Hardanger Fjord, and the rivers flow over it for long distances, often, in fact, for the greater part of their course. Thus the river Bjoreia flows for some twenty miles through the wide open valleys of the Palæic Surface, until at the celebrated waterfall, Vöringsfos, it plunges into the fjord valley. The Vöringsfos is now only seven miles from the snow-field Hardanger Jökul, and the signs of the former extension of the snow and of the presence of glaciers are abundant. Thus the rock of the moorland across which the Bjoreia flows is rounded and ice-marked, and boulders large and small abound. There is a good deal of peat on this moor, and walking over it I was much reminded of parts of the Lewis, though tarns are not quite so abundant here as on that island.

IV.—THE FJORD VALLEYS.

In the last section I explained that the excavation of the Palæic Surface may be attributed to the effect of earth movements, and at some time much more recent a further series of earth movements appears to have taken place. They were in the main movements of elevation, and as the result the rivers have cut a series of deep narrow trenches in the Palæic surface of the district.

Subsequently movements of depression have occurred, and the trenches are now to a considerable extent submerged beneath the waters of the sea, the submerged parts being the fjords.

A similar series of events has taken place in Scotland, where the fjords are often spoken of as sea-lochs.

The final earth movements have been movements of elevation, and many gravel terraces and raised beaches are left as evidence thereof.

There is now a general agreement that the fjords and sea-lochs are partially submerged valleys, but there is considerable difference of opinion as to the manner in which these valleys were excavated, and as to the date of their excavation. The rocks of the Bergen

District are so ancient that they do not assist us in deciding the question of date, and in Scotland, too, most of the valleys of the sea-lochs are cut in very old rocks.

The islands of Skye and Mull, however, are mainly formed of volcanic rocks of early Tertiary age, and the long east and west dykes which are found in central Scotland are also of Tertiary date, and Sir Archibald Geikie ("Scenery of Scotland," 2nd edit., 1887, pp. 145-153) has collected evidence to show that a very great amount of erosion has been effected since these volcanic sheets flowed, and the dykes were intruded into the rock. In particular he mentions Loch Scriden in Mull, and the great valley of Loch Lomond, as evidently more recent than the volcanic sheets and dykes, and if the agents of subaerial erosion have been able to excavate these great hollows since early Eocene times, there seems no *prima-facie* objection to a theory which supposes that the fjord valleys of Norway or Scotland are to a great extent post-Eocene in age.

On the other hand there is evidence to show that the valley of the great glen which crosses Scotland from the Moray Firth to the Linnhe Loch was a valley before the Old Red Sandstone Period, for a tongue of that formation runs a long way up it (see Sir A. Geikie, *op. cit.*, p. 234, note). It is pretty clear that the valley of the great glen follows a line of fracture or of weakness in the crust of the earth, and probably this is the case with most of the valleys of both Norway and Scotland. It is therefore highly probable that many of them are very ancient, though they may have been deepened and enlarged in comparatively recent times.

These remarks apply to most of the fjords, lochs, and channels on the Scottish and Norse coast, but do they also apply to the great channel which, as I have mentioned, runs outside the islands along the coast of Norway? I am inclined to think so, and, further, I suspect that, like the valley of the great glen in Scotland, the channel in question follows the line of a fault or of faults, probably of two faults, that in the south with a north-east and south-west direction, and the second having a north-west and south-east trend.

That the fjord valleys follow ancient lines is beyond question. They are almost always in continuity with valleys which originate on the Palæic surface or on a high plateau, and in some cases it can be clearly seen that the fjord valley has been cut along the bottom of a wide, shallow valley of the Palæic surface—cut, that is, along the same line of weakness in the rock.

Though, however, the direction of the valleys is probably nearly always due to a line of weakness in the rock, it must not be supposed that the valleys are open cracks or fissures. I have examined the upper end of many of the valleys and have always found it to be perfectly clear that the valley had been excavated in the rock and had none of the appearance of an open fissure.

Indeed, I have seen nothing at all like a fissure-valley in either Norway or Scotland.

The rivers sometimes, as in the case of the Læra already noticed, enter the fjord valley by a series of rapids, but more often the fjord valley begins with a great chaldron-shaped hollow into which the river pours as a waterfall. The bottom of the higher part of the fjord valley is frequently rather steep and much blocked up by large screes of angular fragments, and it usually does not show signs of ice-action.

Lower down the floor of the valley is flatter, and the rock bottom is frequently hidden by great masses of moraine material, and gradually the rock-walls of the valley begin to show more and more sign of ice-action. Then after a time we come to a point where the bottom of the valley, instead of being filled by moraine material, is occupied by the water of the sea; it is then called a fjord.

Very frequently, a little before reaching the fjord, we find a lake caused by the terminal moraine of a glacier which has been left stretching across the valley, and in some cases it is probable that this lake is in fact the top part of the fjord separated from it by the terminal moraine.

Such are features frequently to be met with in the fjord valleys, and in order to illustrate the points in which the valleys resemble or differ from one another I propose asking you to follow me down some of them from their place of origin to the sea.

V.—SIMODAL.

I will first take Simodal, one of the wildest and most striking of the valleys of Hardanger.

The stream which flows down it has its source in the snow of the Hardanger Jökul and emerges from the glacier, the Rembesdalsbræ, already noticed. The glacier, as I have said, ends in the waters of a lake.

The lake is about a mile long, and almost immediately after leaving it the stream falls into a chaldron-shaped hollow, the fall being known as the Rembesdalsfos.

The chaldron-shaped hollow is the head of a deep, narrow valley running a little west of south. The bottom is rather steep, and there are great screes of angular talus, and in places many large angular blocks.

About a mile from the waterfall the valley enters the northern side of the head of a wider part of the valley, and there the river from the Rembesdal lake is joined by a stream which pours over the southern wall of this second head of the valley as the Skykjefos, and the united streams flow down the valley, which now

has a westerly direction, and is practically the head of the great valley of the Hardanger Fjord. The floor of this part of the valley is concealed under accumulations of stones and sand, no doubt moraine material. This material forms rather extensive flat-topped terraces, the flat top showing that they belong to a time when the valley was submerged to a greater extent than now. The hamlet of Thveit stands upon one of these flat-topped terraces. About five miles from the Rembesdalsfos we come to the remains of an old terminal moraine, which appears to have been laid down under water, for a small section shows stratification. This moraine no doubt marks a pause in the retreat of the ice up Simodal.

In front of the moraine is a wide alluvial flat filling the bottom of the valley until we come to the water of the fjord. The river flowing down Simodal is now adding to the flat, carrying débris from the moraines and terraces, and depositing it in the fjord.

The fjord looks fairly deep a short way out, and if a tolerably rapid elevation of the land were to take place there would be a flat-topped terrace of sand and gravel with a steep slope in front. In this terrace the river would soon cut a channel, and produce a counterpart of the terraces which we saw higher up the valley at Thveit, and such terraces may be seen in nearly all the fjords of Western Norway.

Soon after leaving the land we pass a large fan-shaped talus, descending from the north side of the valley and extending out into the fjord, and a little farther on magnificent faces of rock form the valley walls on both sides of the fjord. This part of the valley is very much ice-worn, far more so than the upper part. This happens in most of these valleys, and is probably due to the fact that the upper part was filled with soft *névé* rather than with ice during the time of maximum glaciation.

VI.—HJÆLMODAL.

Seven miles from the Rembesdalsfos the valley of the Hardanger Fjord widens, and at Vik it is joined on the south side by a tributary which has a general south to north trend, its upper part being named Hjælmodal. The river which flows down it rises on the Palæic surface, and, I believe, descends into the fjord valley at the Valurfos nine miles from Vik.

At Hjælmo, two miles nearer Vik, it is joined by a tributary stream which comes down the east side of the valley as a series of small and particularly beautiful waterfalls, and lower down another stream joins, falling over a nearly vertical face of rock on the west of the valley. As in the upper part of Simodal there are great screes of talus in this part of Hjælmodal.

Five miles from Vik we come to a high mound of moraine

material on the top of which (about 325 feet above sea level) are some very large blocks.

At Saebö a tributary valley joins on the eastern side. This is the valley of the river Bjoreia. I have already alluded to the course of that river over the Palæic surface down to the Vöringsfos, where the deep fjord valley begins with a great chaldron-shaped hollow.

It has been suggested by Dr. Reusch that these great hollows were (No. 8, p. 207) formed when this part of the Palæic surface was covered by ice. The ice becoming broken by fissures above the head of this valley allowed streams of water which flowed over the surface of the ice to fall through on to and to erode the rock. Slight alterations in the position of the fissures in the ice occurred and caused the water to fall on different parts of the rock at different times, thus enlarging the hollow and producing such results as we have here and have already seen in Simodal.

There can be no doubt that the fjord valleys are not open fissures or cracks in the rock, but that they have been excavated, but to what extent the excavation has been effected by running water, and to what extent it is due to ice is a much disputed question.

On the whole I am inclined to think that the actual erosion is mainly the work of water, and it is, I think, not at all improbable that much of the excavation may have been effected by streams flowing in a more or less confined channel under a mask of ice.

Our member, Mr. Henry Preston, of the Grantham Waterworks, tells me he has no doubt that, apart from any chemical action, water will erode the stone sill of a sluice.

He adds that this is the case whether the water contains solid matter or not, the difference between water alone or water plus sand or gravel being merely one of degree.

Prof. Garwood, in a recent paper in the *Quarterly Journal of the Geological Society* (vol. lviii, p. 715) gives an example from Spitzbergen in which a gorge exists under a glacier, and the ice is seen moulding itself down into the gorge. Would not such a process be analogous to the lowering of a sluice where the stream of water was large enough to fill or more than fill the opening below the sluice in the one case, or between the ice and the rock in the other. In a paper (*Proc. Geol. Assoc.*, vol. xi, p. 450) which I had the pleasure of bringing before you in 1890, I pointed out that questions of ercsion largely depend upon the *concurrence of favourable conditions*, and in the case of the fjord valleys the first of the favourable conditions was an elevation of the land. The presence of ice was probably one of the many others.

The valley below the Vöringsfos is named Maabodal, and, as usual, the upper part is steep, with large screes of angular fragments of rock.

In one place a scree has blocked the course of the river and

has formed a small and very beautiful lake, the Maabovand. About a mile and a half from the Vöringsfos the Bjoreia enters what may be called a second head of the valley, very much as in the case of the Simodal stream, though there is no tributary to correspond to the river of the Skykjefos. As in Simodal, too, the valley slightly changes its direction at this point, and its trend is more westerly until it joins Hjælmodal at Sæbö. There are some terraces and a rather large alluvial flat at Sæbö. The flat is at the upper end of a lake, the Eidfjordvand, and this lake occupies the whole bottom of the valley for the next two and a half miles, the rock cliffs rising steeply on both sides.

The lake is caused by a very large terminal moraine which crosses the valley from side to side. The top of the moraine is 350 ft. above sea level and is flat, having clearly been laid down under the waters of the fjord when the land stood at a lower level than now. The seaward side of the moraine has been cut into flat-topped terraces with various levels, upon one of which the church of Vik Eidfjord stands.

The distance from the lake to the fjord is about a mile, and the vast mass of material which blocks the valley for this mile must have been brought down the valley by a glacier which occupied the space now filled by the water of the lake.

VII.—THE SÖR FJORD AND THE GRAVEN FJORD.

I now pass on to the valley of the Sör Fjord which joins the main valley of the Hardanger Fjord, a little more than 20 miles from the Rembesdalsfos. The Sör Fjord valley begins in a pass between Breifond and Seljestad and has a general south to north trend with a slight curve eastwards. Its length is about 45 miles.

A river of some size flows down it to the fjord, and about 8 miles from the watershed there are two very fine waterfalls, the Lotefos on the east, and the Espelandsfos on the west, formed by tributary streams pouring down from the Palæic surface.

Nearly 13 miles from the watershed we come to a lake, the Sandvenvand, corresponding to the Eidfjordvand and, like it, caused by a terminal moraine which crosses the valley. The Jordal river flows into the western side of the Sandvenvand. It comes down a narrow valley with rather a steep bottom, at the upper end of which, 4 miles from the lake, is the well-known Buer Glacier.

The moraine at the end of the lake rises 446 ft. above sea level. The top is covered with great erratic blocks and is not flat like the Vik moraine. No doubt it rose above the water at the time of its formation. On the fjord side of this round-

topped moraine are a series of flat terraces, on the lowest of which Odde stands. At Odde the Sör Fjord begins and occupies the bottom of the valley for the next 24 miles to its junction with the main valley of the Hardanger Fjord.

The Graven valley, to which I next wish to draw attention, has a southern trend and joins the valley of the Hardanger Fjord on its northern side.

The valley begins as a pass, gradually a considerable stream collects in it, and there is a fine waterfall, the Skjervefos, at the head of the usual deep, narrow fjord-valley.

In this narrow valley terraces are well developed, and below them we come to a lake, the Gravenvand, two and a half miles long.

The lower end of the lake is a little more than a mile from the fjord, and the bottom of the valley for that distance is filled with stones and sand, no doubt brought down the valley by a glacier or by streams flowing in, upon, or under ice when a glacier occupied the position of the lake. The opening between the cliffs here is not nearly as wide as at the head of the Eidfjordsvand or the Sandvenvand, and there is not the same great bank across it. Moreover, such sections in the terraces as there are seem to show that they are better stratified than in the former cases. Clearly the material brought down to the end of the glacier was spread out in the fjord as a wide flat up to the level of the water surface. Subsequently elevation took place and a great part of this flat was cut down to a lower level, leaving merely patches of the higher part at the sides of the valley.

VIII.—THE ESSE FJORD.

Passing now to the north of the district, I wish to draw your attention to two valleys which branch from the great valley of the Sogne Fjord, and first I will take the Esse Fjord, which enters the Sogne Fjord at Balholm.

Its length is only two and a half miles, and, unlike the valleys of which I have been speaking, the sea-water runs up to the cirque which forms its head, there being only half a mile of land between the rock wall of the cirque and the water of the fjord.

Along the shore there is a little moraine material and talus, through which the ice-worn knobs of rock project here and there down to the water's edge.

One such knob is seen close to the landing-place at Balholm on the south side of the fjord, and a long tongue of rock projects from the mountains on the north side of the fjord and separates it from the Fjærlands Fjord.

The direction of the fjord valley is easterly, and on its south

side it is joined by a tributary valley 2 miles long and also with a wide cirque at its head. This tributary valley is above sea level and is named the Esedal. A considerable stream flows down it and has thrown a semicircular fan of débris out into the fjord. Above the level of the fan there is a flat terrace which is some 20 ft. above the fjord at its lower end and rises inland. About 20 ft. above it there is a second and less extensive terrace consisting of stones and sand, without, so far as I could see, much sign of stratification.

These flats are apparently the remains of fans thrown down at the mouth of the small river at a time when the land stood somewhat lower than it does now.

IX.—THE FJÆRLANDS FJORD.

The valley of the Fjærlands Fjord runs into a district of high plateaux belonging to the oldest land, and around it the Palæic surface has only been developed to a small extent. As I have already stated, the plateaux are almost covered by perpetual snow, and to show how narrow the fjord-valley is I may mention that near Mundal, where its depth is over 5,000 ft., the Frudals Snow-field on its eastern side is distant only 4 miles from a projecting part of the Jöstefond on the opposite side of the fjord.

This fjord-valley somewhat resembles that of the Sör Fjord, and like it has a nearly north and south trend, though in the present case the head is at the north, whereas in the case of the Sör Fjord the head is at the southern end. The watershed is in a pass, and the first 7½ miles, named the Suphelledal, is land. The remaining part of the valley, 16 miles in length, is fjord.

I have already mentioned some glaciers which descend for a short distance from the snow-fields around this fjord, and I will now give examples where the ice travels far below the snow line and down to the bottom of the valley. The sides of these valleys are in places so steep that the ice does not always flow over its bed in the manner usual with glaciers, but it seems to me that in some cases the ice becomes broken into separate fragments and moves very much as though it were a mass of rock fragments or of stones. In one case, indeed, there is complete discontinuity between the upper and lower parts of a glacier, and I will take it as my first example.

The Suphelle Glacier originates on the great Jöstedal Snow-field, nearly 2 miles south of the Suphellenipa, a peak 5,652 feet high, situated 2 miles north-east of the Suphelledal, the valley in the lower part of which the Fjærlands Fjord lies.

The higher part of the glacier, when I have seen it, has been much hidden by snow, but it evidently travels down a fairly steep

part of the high plateau, and the ice seemed to be a good deal broken by crevasses.

The direction of this part of the glacier is nearly south, and about one and three-quarter miles from its source at a level of some 3,000 feet the ice reaches a fairly flat and open space. On this open space the ice has deposited a considerable moraine, which has many of the characteristics of a terminal moraine. Thus it lies nearly at right angles to the course which the glacier has up to the present taken, and so far as one can see, there was no reason why the glacier should not have continued that course, for the moraine overlooks the valley in that direction. Moreover, the ice has formerly extended somewhat farther in that direction, for there are other moraines more or less overgrown outside the present one. The glacier does not, however, end here, but turns to the left, and after a short and tolerably level space the ice falls over the steep side of the Suphelle Valley. Why the glacier makes this turn and deposits a large moraine across its former course is not easy to say; probably it is due to the shape of the rock valley beneath the ice. Anyhow, the ice does turn here, and with such determination that it impinges against the rock on its left side, the ice on that side being raised somewhat above the general level of the glaciers at this part.

The ice falls over the western side of the Suphelle Valley at a point where that side is between 2,000 and 3,000 feet high. At first the slope is not very steep, and the ice advances as a mass of more or less broken fragments, but soon an almost vertical cliff is reached, and the fragments of ice, together with the moraine stuff on, in, or carried with the ice, fall over from time to time. Some streams of water, which have no doubt been flowing beneath the upper part of the glacier, fall over with the ice.

The fallen ice forms a great cone at the foot of the cliff, and becomes consolidated into a new glacier, a *glacier remanié*, which advances out into the middle of the valley. The floor of the valley is here about 800 yards wide, and the ice now advances about a third of the distance across, but old moraines show that it has at no distant time nearly or quite crossed the valley.

The *glacier remanié* is very well shown in the photo published by De Seue in 1870 (No. 5, see plate at end of his work). The ice is divided by long radial cracks or fissures, and is beautifully laminated.

The amount of moraine material brought over the fall is very large, and the *glacier remanié* is much covered by débris. In front there is a great desolate space with numerous curved moraine mounds marking former sites of the semicircular foot of the ice. This moraine covered space extends not only in front of the ice, but up to the rock wall at both sides of the glacier.

There are usually one or two more or less well-developed

caves at the foot of the ice. They vary in number, size and position in different years.

Besides the curved moraine mounds I noticed several radial mounds running out from the front of the ice. They are due to the radial fissures in the ice. As the ice melts along these fissures tongues of ice, sometimes of considerable length, are left, and the stones and sand in and upon the ice has, as the melting proceeds, a tendency to fall between the projecting tongues, the result being radial moraine mounds.

There is a wide desolate space in front of the ice, and as we go away from the ice the moraines become more and more overgrown. I daresay these sandy and stony heaps are not very favourable to plant life, but the fact that the outer ones are overgrown shows that plants will grow, and their absence near the glacier shows that the ice has been further advanced than now not so very long ago. In short the mere appearance of the ground in front of the ice satisfies me that this glacier has on the whole retreated greatly in modern times.

I will now pass to the Bojum Glacier which flows into the Bojumdal, a tributary to the valley of the Fjærlands Fjord.

The Bojum Glacier originates on the Jostedal Snow-field about 2 miles south-west of the Suphellenipa. It is of a more normal character than the Suphelle Glacier, and may be matched by many examples in the Alps. It flows for a short distance over the high plateau and then over the head wall of the Bojum Valley.

The end of the valley being hidden by the ice, I cannot say what its shape may be, but I fancy the upper part at least is very steep. In any case the ice is very much broken for some distance from the crest of the valley side, and I should describe that part of the Bojum as an ice-cascade rather than as a glacier. The stream of ice is, however, continuous, and lower down the ice again becomes consolidated. The foot of the glacier, as is usually the case, varies greatly in appearance in different years. In 1896 there was an imposing cave in the middle of the front. In 1898 there was very little sign of a cave, and in 1901 a small cave had appeared in the right side of the front, and in quite a different place to the cave of 1896.

The ice is marked by bands of colour, but there is not the laminated appearance which is so well marked in the *remanié* part of the Suphelle Glacier.

Dealing with the Norse glaciers as a whole, Professor E. Richter ("Beobachtung über Gletscherschwankungen in Norwegen, 1895," Petermann's *Mittheilungen* for 1896) came to the conclusion that they have not retreated nearly as much as those of the Alps during the last fifty years. The question has recently been reported upon in a memoir of the Norwegian Geological Survey by J. Rekstad (No. 7). He thinks that Professor Richter's conclusion was too hasty, and that the Norse glaciers have on

the whole receded greatly during the last century, and not least during the fifty years before 1899.

With regard to the Bojum Glacier, Mr. Rekstad found local evidence of inhabitants that it has retreated a good deal since 1868, and a comparison of a number of photographs of the glacier taken from 1868 to 1899 led him to the conclusion that the glacier had increased in size from 1868 to about 1870; that it had retreated from 1870 to about 1880, again advanced from 1880 to about 1888, and has again retreated from 1888 to 1899.

Mr. Rekstad thinks that in 1899 the upper part of the glacier had begun to increase again. I first saw the glacier in 1896, and a photo which I took bears out Rekstad's conclusion, for it certainly shows less ice than De Seue's photo of 1868 (No. 5) or Lindhall's of 1886 (No. 7).

In particular there is a patch of rock on the high left side of the glacier showing through the ice in my photo, which does not appear in the older ones.

Rekstad mentions this patch, and says a local inhabitant told him it was bigger in 1898 than in 1899, and from this Rekstad infers that the upper part of the glacier had begun to increase again, and I think this is the case, for when I was there in 1901 the patch was not to be seen.

Thus the Bojums Glacier was at a minimum of extension in 1867, 1880, and 1899, and at a maximum in 1870 and 1888. These dates are merely approximate, but I have no doubt that Rekstad is right in thinking that during the period as a whole the glacier has retreated; and, apart from other evidence, the wide extent of the desolate space in front of the ice leads me to suspect that the retreat has been considerable.

Beyond this desolate space are overgrown moraines, and there are considerable masses of sand and stones, probably of moranic origin, between the glacier and the fjord.

The bottom of the ice is 390 feet above the sea, and it is $2\frac{3}{4}$ miles from the alluvial flat at the head of the fjord, and 4 miles from the fjord itself.

In the upper part of the valley there are mounds of large and small stones, sections in which show no stratification, and which are no doubt moraine mounds. As we follow them towards the fjord they pass into a great bank looking like a railway embankment. The top is fairly flat, and it may very probably have been laid down under water. A little lower there is a very flat-topped terrace upon which are several houses, and which I have no doubt was laid down under water. It is about 150 ft. above the fjord, and when the terrace was formed the land lay some 150 ft. lower than now, or the water of the fjord stood higher. At a rather lower level there is another terrace, also flat-topped, which slopes down towards the fjord. There are flats at various levels on both

sides of the river which runs down the valley, and a little above the level of the alluvial flat there is a mound in which I noted the following section:

1. Gravel, mostly rolled stones up to 6 in. in length... ... 1 foot
2. Sand, with a small stone here and there. Evenly stratified and not current-bedded... ... ... 10 feet.

Sections in the terraces near also show stratification, and I suggest that they and the mound consist of moraine material washed down into the fjord.

At the head of the fjord there is a flat $1\frac{1}{4}$ miles long, and extending across the valley which is here half a mile wide. It is largely covered with cornfields, and several farms stand on it. The lower part is muddy, and at low water a mud flat is exposed running a little way out into the fjord, where it evidently ends with a steep slope, for the fjord is 43 ft. deep close to the shore.

The mud flat is formed of material brought down by the river which flows into the head of the fjord, and it is now in process of extension.

It is uncovered at low water, and Mr. Herries and I found a considerable number of molluscs living upon it, the commonest species being *Mya arenaria.*

I have, I think, now dealt with some of the more striking features of the land surface of the Bergen District, and I have tried to give examples of the chief varieties in hill or valley. On many of the questions to which I have drawn attention I have hesitated to give a very definite answer. In fact, I believe that the answers are in many cases not yet known; when someone discovers them we shall all say: How simple! How was it we never thought of that before!

During our excursions in the coming season I hope we may have an opportunity of seeing many interesting results of subaerial erosion, and of considering in the field some of the problems to which I have alluded this evening, and in particular, I hope, during our Easter excursion, to have the pleasure of hearing some remarks on the very interesting river valleys in the neighbourhood of Salisbury.

THE FORMATION OF CHERT AND ITS MICRO-STRUCTURES IN SOME JURASSIC STRATA.

By CATHERINE A. RAISIN, D.Sc.

[PLATES XIV and XV.]

(Read December 5th, 1902.)

Introduction.

CHERT is attractive even superficially in the curious forms which it exhibits, and in the picturesque features of cliff and scarp which it helps to develop. It is a subject well-fitted for discussion here, since numerous examples of the rock are found in English localities, associated with many formations.* Most of these would be more or less typical in the character of the problems they present, and I have selected examples mainly from Jurassic rocks. To mention others, however, the early Radiolarian cherts of Ordovician age and of the Culm Measures are known through recent investigations. The massive chert of Carboniferous Limestone is a marked feature in Derbyshire, in North Wales and Ireland, in the Mendips and elsewhere. Chert of perhaps Rhætic age occurs in the last-named hills at Harptree, and Permian silicified wood is found in some Midland localities. The Jurassic cherts yield much material, chiefly among the Upper Oolites. In Dorsetshire the fine cliffs and quarries of Portland Isle, and the cliffs along the Isle of Purbeck, often an almost continuous series of quarries, give excellent study for this investigation. Equally valuable are many quarries in the Vale of Wardour, as at Tisbury and Chilmark. Chert can be followed at places in the Lower Greensand from Hindhead and Leith Hill to Maidstone and beyond, and in the Upper Greensand from Dorset or farther west to the Isle of Wight and Kent. While

* The subject was treated by Prof. T. Rupert Jones in parts of the paper "On . . . Forms of Silica . . ." *Proc. Geol. Assoc.*, 1876, vol. iv, p. 439. Also in the Appendix to the interesting account of the Vale of Wardour given by Mr. Hudleston, *Proc. Geol. Assoc.*, 1881, vol. vii, p. 180.

flints in the overlying Chalk can be tracked over a wider area and even in Tertiary beds a little poor chert occurs.

A preliminary question is the difference of chert from flint, but it is not easy to define precisely.* Distinctions can be drawn between typical specimens, but various gradations connect such types. Thus flint is more often in nodules but may be in layers; chert frequently builds up layers but may be in nodules. Chemically, chert has, on an average, a rather lower percentage of silica—has more impurities in it (the substance chiefly associated being carbonate of lime)—but the silica percentage may rise until this distinction from flint disappears. Specimens of flint have usually a conchoidal fracture, chert a splintery. The microscopic structure of flint is generally finer grained, more uniform, containing some colloid silica†—that of chert often more varied and more coarsely cryptocrystalline. But the homogeneous character may be lost from parts of flint; may be taken on by chert. Notwithstanding the gradations, these distinctions (especially that of texture) might perhaps be used if we apply them to any mass or fair-sized specimen, not to a microscopic slice; thus certain very compact bands or nodules in the Portlandian strata would be termed flint.‡ This would be more useful than the common practice of retaining that name for structures in the chalk, and chert for rock elsewhere.

I have visited many examples since I began some years ago to study various specimens of chert§ in the hope that the investigation might throw light on the micro-structure of certain rocks, and the results of crystallisation in different minerals; and it was my intention to limit my discussion to this point of view. But I was led necessarily to some observations which bear upon the general development of chert, and it seemed more useful to include these considerations. I have therefore used a wider title, although these notes are only a small and limited contribution to the work which has been done by more experienced investigators.

The various views as to the origin of the rock have been formulated generally in connection with special cases, and, as has been pointed out by other writers, the origin of different examples may have differed. One possible hypothesis is that the chert (or flint) as we now see it represents the original condition of the solid rock, and that the silica was drawn directly from the waters of sea or lake by chemical precipitation and laid down in colloid

* See Prof. T. Rupert Jones, *Proc. Geol. Assoc.*, vol. iv, p. 448.

† *Cf.* Prof. Judd, "On the Unmaking of Flints," *Proc. Geol. Assoc.*, 1887, vol. x, p. 218.

‡ They are so named by Mr. Hudleston, *Proc. Geol. Assoc.*, vol. vii, p. 180.

§ Some of my earliest study in the field was made during certain of the annual geological expeditions conducted by Professor Bonney for his students from University College.

form. Instead of this process the silica may have been extracted from the water by the action of organisms, and then directly deposited to form the chert. More probably the two processes might have combined, so that if the chert were a contemporaneous formation it represents a nucleus, generally of siliceous skeletal parts, sometimes even of other organic centres, to which a colloid silica from the water or surrounding mud had aggregated, as is described by Prof. Prestwich for the flints of the chalk.*

Many writers consider that chert represents a secondary condition of a rock originally different, generally a limestone. Some authorities who have given the most definite statement of this view have maintained that the deposit occurred partly or wholly during the formation of the beds.† The source of the replacing mineral in the pseudomorphism has to be inferred, and in those rocks it was described as colloid silica deposited by chemical precipitation. Other authors have maintained that the pseudomorphic replacement occurred in a subsequent period.‡

The presence and often abundance of siliceous organisms, however, has been shown in many cherts by Dr. Hinde,§ by Prof. Sollas,‖ and by others, and to the former author we owe the investigation of these organisms in various formations from widely distant localities. The evidence is claimed as proving in these rocks, or establishing for chert generally, that the silica was organic in its origin. In this contention the question as to the epoch of deposit is often not discussed.

Thus the main problems to be answered are whether chert is contemporaneous or subsequent—whether it is from inorganic sources or due to organisms. The latter is the question to which recent investigations mainly refer, but, in these Portlandian beds, I have attempted to consider first the previous problem.

I. ORIGIN OF CHERT—Epoch of Formation.

We see in the field that chert frequently occurs in a massive stratum, which often tails off or extends as an elongated lenticular layer. This might be formed as an original deposit or might result from secondary change, but the layer sometimes ends abruptly, which would be more difficult to explain on the former hypothesis. A fine lamination and current bedding are clearly

* *Geology*, p. 323.

† Prof. Hull states that it was "during and after" the formation of the limestone before the overlying beds were deposited. Both Prof. Hull for Ireland and Prof. Renard for Belgium describe the process as occurring in the Carboniferous Limestone while the strata were "in a pasty condition." *Trans. of Roy. Dublin Soc.*, vol. i, n. s., 1878, p. 82, and *Bull. de l'Acad. Roy. de Belg.*, 1878, 2 s., t. xlvi, p. 497.

‡ *Cf.* C. R. Keyes, *Am. J. of Sc.*, 1892, ser. 3, vol. xliv, p. 451, "that the siliceous impregnation had been acquired long after the original deposition of the beds."

§ *Geol. Mag.*, 1887, 3rd ser., vol. iv, p. 435. *Ann. & Mag. Nat. Hist.*, vol. vi, ser. 6, p. 40, 1890. *Phil. Trans.*, 1885. *Pal. Soc. Mem.*, British Fossil Sponges.

‖ *Ann. & Mag. Nat. Hist.*, 1881, ser. 5, vol. vii, p. 141.

seen in many Portlandian cherts, as at Tisbury and parts of Portland Isle, and the latter structure especially seems suggestive of the deposit of clastic materials or true sediments, as if the chert had resulted either from the accumulation of siliceous fragments or from the pseudomorphism of a previous fragmental rock like a fine calcareous grit.*

Another mode of occurrence often described for chert and flint is in bands transverse to the stratification. Thus in one of the large Chilmark quarries in addition to the roughly horizontal strata, bands of chert extend both obliquely and at right angles to the lamination, generally tailing off at the end in a wedge fashion, but enlarged at intervals, thus becoming somewhat moniliform or knotted in appearance. Such bands often seem to follow joint planes and may have been deposited either as veins in cracks or spaces, or, starting from the plane of weakness, might represent an infiltration and change of the neighbouring rock.† Both in hand specimens and in slices examined under the microscope, traces of organisms can sometimes be seen,‡ and although some fragments might be enclosed in a fissure, the chert in many examples is evidently a silicified part of the sedimentary mass.

The occurrence of nodular chert yields perhaps even more definite suggestion. The layers already described at Chilmark as ending abruptly, seem sometimes continued beyond by a line of nodules, and, like the transverse bands, the layers may be moniliform. In other cases isolated nodules are scattered through the rock, varying in form, sometimes very irregular, sometimes rounded or elongated, and even thinning out along bedding planes showing relations to the lenticular bands previously described. Other rock surfaces expose a ring of chert, the section of a spheroidal shell which surrounds rock not silicified. The size of nodule or ring is various, from one inch or less in diameter to one foot or more. At Tillywhin, below the fossiliferous freestone, the section of the cliff includes layers of chert along the strata, sometimes cross bands in a vein-like form, and many nodules, small and large, and occasionally a ring of chert. At one part the irregular, rather small nodules project in high relief on the weathered surface of the limestone. To account for the nodules of chert by any original deposition we must suppose that the silica was laid down in the plastic ooze of the sea bed in spots and patches. It seems doubtful if in such cases the chert would exhibit, as perfectly as it often does, the lamination and other characters of the adjacent mass. Indeed the formation of a large nodule (one foot across or more) within

* It is almost needless to say that the siliceous material does not now exhibit a fragmental character. Even if this had been originally shown, it would have been modified by subsequent change.

† See Prof. T. Rupert Jones, *Proc. Geol. Assoc.*, vol. iv, p. 450. Mr. Hudleston, *ibid*, 1881, vol. vii, p. 183.

‡ *Ibid*, Pl. I, figs. 3, 4.

the plastic ooze would not be easy to understand, and the "rings of chert" especially would be difficult to explain. In some nodules. structure planes occur roughly parallel with the circumference, but these are like wave marks of infiltration. Moreover, comparison may be made with various "concretions," such as the ferruginous nodules of the Neocomian, and these are often hollow, thus like the "chert rings" except that in the ferruginous sands the material within the crust is more often removed. The cementing of sand grains is a different process, but it is caused by infiltration.

By study with the microscope, we often find fragments of calcite crystals or organisms scattered in the siliceous ground, and they are doubtless generally *residua* left after partial replacement (Pl. xiv, fig. 3). In banded strata the change from limestone to chert might be partly due to changed materials of deposit, like the gradual passage from calcareous grit to limestone or sand. But the transitional zone, with numerous calcitic *residua*, occurs also where the boundary crosses the stratification, and thus must be due to secondary alteration.

Numerous calcareous structures show clear evidence of gradual attack and corrosion*. They often exhibit a crenate margin with rounded chalcedonic ingrowths. Gradually the siliceous deposit seems to extend, and towards the last the ghostly remains of the original calcite may be seen in the midst. These replaced structures are often parts of shells or other organisms. This is clearly seen even in the field or in hand specimens. The silicified *Isastræa* of Tisbury is not common, but the quarries in that locality exhibit beautiful examples of Trigonias and other mollusca now formed of chalcedonic silica. These can be studied in detail in the microscopic slides. Among the organisms which can be recognised are Foraminifera, Corals, Echinoderms, and Mollusca.

Another structure of great interest may be compared—that of the silicified oolite.† The silicification extends sometimes within an irregular boundary like that of a nodule. Study with the microscope shows that gradations and transitions are here even better marked than in other cherts. In specimens from Portland a calcareous oolite adjoins, and is evidently becoming modified into a rock completely siliceous. In one slice oolite grains in a transitional zone stretch across the boundary, and each is itself partly calcareous, partly silicified. Other rocks exhibit calcareous oolite grains embedded in a silicified ground (Pl. xiv, fig. 1). In others the grains are partially attacked, not always in the same

* *Cf.* M. Renard, *Bull. de l'Acad. Roy. de Belg.*, 1878, 2 s., t. xlvi, pp. 471-498, Pl. I. *Cf.* Mr. Hudleston, *Proc. Geol. Assoc*, 1881, vol. vii, Pl. I, Figs. 5, 6, p. 184.

† See *Geol. Surv. Mem.*: "The Middle and Upper Oolitic Rocks of England," edited by H. B. Woodward. Results of the examination of a partially silicified oolite from Chilmark by Mr. Teall are given, p. 234. *Am. J. Sc.*, 1890, ser. 3, vol. xl, p. 248, E. H Barbour and J. Torrey. Also 1897, ser. 4, vol. iv, p. 202, G. R. Wieland.

manner (Pl. xv, fig. 8). In recent discussions the formation of the silicified oolite of Pennsylvania has been attributed to the action of siliceous springs.* That rock, however, occurs scattered on the surface of the ground, associated with blocks, claimed as parts of the geyser basin. And, comparing a slice of the Pennsylvanian oolite, it exhibits differences from the Portlandian examples. The grains are generally more circular in section, show a more marked concentric structure, and an external, sharply-defined, more nearly homogeneous crust. They bear more resemblance to the pisolite of the hot springs at Carlsbad, only in different material.

Occasionally some minor character can be traced continuously from limestone to the adjacent chert, as in a specimen from near Gadcliff, which has a slightly cavernous structure. The small cavities are exactly similar in the two materials, and in both are filled with chalcedony.

Among the results of a pseudomorphism in the Portlandian chert, the siliceous deposit along planes apparently due to jointing, even the abrupt or truncate ending of various layers, and the occurrence of large rounded nodules and "chert-rings," are all suggestive of a later replacement of the solid rock. And it would be difficult to imagine that the same sea, which allowed the formation of the oolite, yielded an infiltration of water containing silica to attack and replace the oolitic grains. Further, no indication seems given that the nodules or "rings of chert" occupy patches which in the pasty ooze were more easily attacked.† Thus the evidence (apart from any question as to the origin of the silica) proves a pseudomorphism, and makes it probable that this was subsequent to the consolidation of the rock.‡

II.—MICRO-STRUCTURES.

The study with the microscope of silicified rocks raises some questions of theoretical interest, such as the order in the processes of mineralisation, its connection with structures in the rock, and their influence on the form assumed. Some problems are suggested by comparison with rocks of a different origin. If we place side by side the slice of a cryptocrystalline acid igneous rock and certain of these cherts, the likeness is often marked, and thus investigation of the latter may perhaps throw light on the more obscure processes which have occurred in the former.§

In siliceous rocks, a uniform, fine-grained character is familiar

* *Am. J. Sc.*, 1897, ser. 4, vol. iv, p. 262. G. R. Wieland, "Eopalæozoic Springs."

† As suggested in the paper, "On the Chemical Composition of Chert." E. T. Hardman, *Trans. Roy. Dublin Soc.*, 1878, p. 94.

‡ *Cf.* C. R. Keyes. *Am. J of Sc.*, 1892, vol. xliv, ser. 3, p. 451.

§ *Cf.* F. Rutley, *Quart. Journ. Geol. Soc.*, xxxv, p. 327.

(as in many chalk flints), but chert shows often a heterogeneous or differentiated structure, and the explanation of this in each case is an interesting and often not easy problem. It may be partly connected with the succession in the silicification. The more usual order (although with some exceptions) seems to be: first, change of the ground mass; secondly, of organisms or oolitic grains*; thirdly, of large crystals of calcite. Thus in partly silicified rock, the residual calcite (which is often dolomitised) is embedded in a siliceous ground, and oolite grains or parts of them are found similarly surrounded. A reversal of this order if it occurs is generally very local.

It is difficult to conclude how far different organisms are differently affected. Silicified fossils from various groups occur, but most classes are only sparsely represented in these Portlandian rocks. The numerous examples to which I have referred are Mollusca.

The last structures to yield to modification seem to be any large calcite crystals. This may explain a characteristic feature of the Crinoidal chert from the Carboniferous Limestone of Derbyshire and other localities which exhibits silicified casts.† In the unweathered rock the crinoid stem consists (as is common) of well-cleaved crystalline calcite. Thus its resistance to silicification may be due to this character, as is suggested by Prof. T. Rupert Jones and by Prof. Renard.‡ As a corroboration we find that the actually silicified echinoderm plates or ossicles, so far as I have seen, are those which retain their columnar network, thus possibly those which still had an organic structure. The partial preservation of the substance of a Serpula in a rock otherwise silicified (from Winspit) is perhaps due to its massive calcareous character (Pl. xiv, fig. 4).

The present structure of the silica in chert may sometimes be a modification of an earlier form of deposit. Often a small border of radial or mammillated chalcedony appears without polarised light as a uniform pale brownish substance like a deposit of opal.§ The resemblance is more marked in certain patches traversed by white lines, like the cracks in the drying mud of a pool, although with crossed nicols the substance is seen to consist of chalcedonic tufts. The silica may have been deposited in colloid form and afterwards modified.

The heterogeneity in chert, however, must be largely due to the influence of original structures in the rock. If cavities

* *Cf.*, however, Mr. F. Chapman "On Oolitic . . . Limestones . . . from Ilfracombe." *Geol. Mag.*, 1893, dec. 3, vol. x, pp. 100-104.

† It is interesting to learn that the same results are shown in Carboniferous Crinoidal chert from America. See *Am. J. of Sc.*, 1894, ser. 3, vol. xlviii, p. 401. "Cherts of Missouri," E. O. Hovey.

‡ By Prof. T. Rupert Jones in *Proc. Geol. Assoc.*, vol. iv, pp. 447, 449, 1874-6. By M. Renard, *Bull. de l'Acad. Roy. de Belg.*, 1878, 2 s., t. xlvi, p. 488.

§ *Cf.* E. O. Hovey, *Am. J. Sc.*, 1894, ser. 3, vol. xlviii, p. 401. *Cf.* Mr. Hudleston, *Proc. Geol. Assoc.*, 1881, vol. vii, p. 183.

existed, the infiltrating silica apparently filled them with a clear deposit of chalcedony like that in amygdales or small agate nodules, sometimes forming a radial or spherulitic border and a central mosaic. Such cavities exist in the chambers of organisms, but some occur in a slice cut from a chert ring at Gadcliff, both in the slightly cavernous limestone and in the adjacent chert, or even extending across the boundary. The chert consists of a fine-grained siliceous ground mass, and the cavities are filled with clear chalcedony. No calcite is deposited within them, even in the limestone, as if the infiltrating silica filled these spaces first and before it would attack the surrounding mass.

The shells of Mollusca replaced by silica generally exhibit radial arrangement along the margin with an interior of clear, granular chalcedony (Pl. xiv, fig. 5). In the fragments which have the close columnar network of an echinoderm* (and in other reticulate structures) the chalcedony has spread as a fine granular mosaic, the minute network being sometimes picked out by a brown staining. Thus a fragment with well-defined boundary and with structure planes parallel or normal to it (like a shell) seems to start radial growth, but where the structure is a network extended in various directions, a granular deposit is formed.

The silicified oolite grains have generally a narrow marginal zone, often finer grained, and with radial and sometimes concentric structure. Within this is a granular chalcedonic mosaic, often clear, but sometimes with a brown-stained irregular network. The replacement can be traced in different ways. Generally it proceeds from the exterior, forming crenate ingrowths (Pl. xiv, figs. 1, 2), or extends to a ragged and irregular limit. In a late stage the mosaic in the oolitic grain is spread over scattered specks of calcite which indicate faintly the remains of concentric structure. Sometimes the oolite grain exhibits concentric layers of residual calcite alternating with zones where silica has been deposited. One interesting oolite (a very local development in the Lower Oolite north of Frome†) consists of oolite grains separated by well-crystallised dolomite ‡ (Pl. xv, fig. 8). They are themselves partially replaced, but the silica has spread irregularly, often aggregated towards the centre of the grain, or scattered in granules among residual calcite.

The larger crystals of calcite are corroded from the edge (Pl. xiv, fig. 3), but are replaced within by a granular mosaic extending over cleavage planes, of which faint traces persist. Where such a regular structural hindrance occurs, it appears to

* These fragments are small and few in the Jurassic rocks, but they exhibit the same character in other cherts (*e.g.* Carboniferous). Since I wrote the above, Prof. Lloyd Morgan has kindly sent to me a slide exceptionally rich in replaced echinoderm fragments from the carboniferous chert of the Mendips.

† I am much indebted to Mr. H. B. Woodward for kindly telling me of this locality when I was conducting an expedition for students in that neighbourhood.

‡ *Cf. Ann. Mag. Nat. Hist.*, 1881, ser. 5, vol. vii, p. 142, Prof. W. J. Sollas; also M. Renard, *Bull. de l'Acad. Roy. de Belg.*, 1878, 2 s., t. xlvii, p. 486.

cause the spreading of coarser granules. In some cases, especially of organic structures, as in a shell, it may even induce a definite orientation of the grains. Where they develop under less constraint they sometimes exhibit angles or a hexagonal outline, evidently an incipient crystal form.

The interspaces between any enclosures are occupied often by a fine grained cryptocrystalline ground mass. This seems more common where much foreign material—mud or fine irony deposit—is present. In other cases a radial growth may start from the enclosure, whether crystal or organism, or oolite spherule or sand grain. In narrow interspaces the radial growth may give rise to confused spherulites, in wider intervals may be followed by an infilling mosaic (Pl. xiv, fig. 5).

Thus among the principal differentiated structures in a chert, a radial development is evidently one of the most important. Since, however, the exact character of the original structures modifies so slightly the forms assumed, when silicification is complete it is clear that it will be difficult to recognise what those structures were, except by their outline. The frequent formation of chert from limestone is connected with the ready solution of the carbonate. Where dust is present it may remain, and thus the clearer spaces in a developed chert often mark the former presence of organisms, whether originally calcareous or siliceous. The origin of many differentiated patches, however, can at most be only surmised.

Throughout these rocks (and elsewhere) silica seems to exhibit certain tendencies. Just as actinolite grows usually into elongated prisms, the more marked in form when opposed by the resistance of finely-divided material,* so chalcedonic silica tends to grow into close radial groups or to develop spreading granules.† The forms of chert are mainly modified (first) by this tendency in chalcedony, (secondly) by the presence of starting points for its growth, (thirdly) by the effects of pre-existing structures.

The irregular and differentiated appearance then presented bears often a remarkable resemblance to many Felsites. Certain distinctive structures can be paralleled in the two rocks. A felstone is often a granular cryptocrystalline mass, the modifications in which may be due to a radial or tufted growth, or to an elongation of irregular constituents, or to an incipient development of crystals. Spherulitic forms on the one hand or micropegmatitic on the other may result. The variations are imitated in cherts (Pl. xiv, fig. 4); even a kind of micropegmatite is to be seen sometimes, but it may be not easy to infer exactly what structure it replaces. The forms assumed in a felstone, like those in a chert, probably are mainly governed by the heterogeneity of the original mass, not by the actual character of its different parts.

* Prof. T. G. Bonney, *Quart. Journ. Geol. Soc.*, 1898, vol. liv, p. 369.
† *Cf.* M. Levy, *Mineralogie Micrographique*, pp. 194, 196.

In the felsite, similar developments may start from the surface of the streaks in a fluidal glass, or from included fragments or crystals. The deposit, however, may be sometimes modified by pre-existing structures. Where the crust of a pyromeride exhibits large irregular granules, they are often elongated radially. This might be caused if a later alteration had taken place in a spherulitic structure, which influenced the form and direction of the secondary granules.

III.—ORIGIN OF THE SILICA.

In the first part of this paper, I laid stress on the process of change in the formation of chert, and I had originally no intention of discussing what might have been the earlier condition of the silica. Reference to this question in connection with Jurassic rocks has been made in more important memoirs.* But the specimens I have examined present certain evidence which ought to be recorded. The investigation has warned us what difficulties will be caused by the obliteration and change of previous structures. Often it will be doubtful whether traces of organisms once occurred, and negative evidence of many slides must be expected. While the advocate of an inorganic supply has even a greater difficulty, since an organism may be capable of recognition, a speck of precipitated colloid silica cannot.

In many slides of the chert, sponge spicules can be clearly identified, some resembling the Tetractinellid *Pachastrella* described by Dr. Hinde from the Isle of Portland and Upway,† or, in one case at least, a possible *Geodites;* and the sections of spicules are abundant at certain parts. But the exact distribution may be an important fact. In a junction slice of limestone and a chert nodule from Tillywhin, sparse scattered spicules occur in the limestone, but on the border of the nodule they are crowded, where a few can be recognised in longitudinal, many in transverse section (probably *Pachastrella antiqua*) (Pl. xv, fig. 7). In another nodule from Winspit, the sponge spicules include one larger, possibly *Geodites* (Pl. xiv, fig. 6), and abundant sections of a smaller form (? *Pachastrella*), while in a banded chert from the same locality they are also numerous. Some specimens occur in a silicified oolite from Portland Bill in the part of the slide where the oolite is more sparse. Spicules have already been recorded by Dr. Hinde in nodules from other Dorsetshire districts.‡ In these cases, the silica seems probably derived from organisms, which grew, or died, or drifted—on the particular spot, and the mineral substance was not carried far.

* *Pal. Soc. Mem.* "British Fossil Sponges," Part III, p. 193.
† *Pal. Soc. Mem.* "British Fossil Sponges," Part III, p. 209.
‡ From Isle of Portland, and Upway, *ibid.*, p. 193.

If the chert is largely a pseudomorphic rock, and if the silica is derived from siliceous organisms, we must consider whether they can be traced usually in such close proximity, and how far this would be an argument for the early and almost contemporaneous formation of the chert. On the former of these two problems, wider observations must be consulted, but even some of the rocks which I am describing suggest a contrary view. On the latter, we may recall the modes of fossilisation so clearly described by Dr. Hinde, showing the changes which are exhibited in the mineral substance of sponge spicules.* Such modifications occur slowly and occupy time. Since, however, organic structures yield silica which is readily soluble, the changes include the possible conveyance of the silica through the neighbouring rock —the mineral might be transferred as well as transformed—and this might occur at some later epoch after consolidation of the mass. The possible transformation from opal to chalcedony† would thus give no evidence on the question of original precipitation. By the solution of any silica it might be transferred and deposited in colloid form. Indeed, as in various rocks, a mineral may have passed many times through a certain condition before it reached its present resting stage. If the silica was originally mainly organic, for the process of silicification in so much rock and so many calcareous structures hosts of sponges or their like must have been destroyed, of which we can see only some remnants. This would probably offer no difficulty, but I leave to others better acquainted with living growths to make more definite statement.‡

Thus, finally, if we try to summarise the history of cherts, it is clearly somewhat various in different rocks. Some, like the Pennsylvanian oolite, might be direct deposits of hot springs, although even then the action of lowly Algæ may have caused the extraction of silica from the waters if the conditions were like those described by Mr. Weed.§ In some cherts it is possible that the silica from the sea of the period may have been directly deposited within the ooze, but positive evidence for this view would be difficult to obtain, and I can record none in these Portlandian cherts. Often limestone strata accumulated, with siliceous organisms more or less numerous and perhaps locally distributed. In the molecular changes afterwards going on in the rocks, infiltrating water removed the soluble carbonate, and substituted, in patches or layers, the silica previously occurring

* Dr. Hinde records among fossil sponges only some Tertiary spicules, in which the silica is similar to that in recent sponges, in being in colloid condition and beautifully clear like perfect glass.—"British Fossil Sponges," Part I, p. 54.

† See *ante*, p. 73.

‡ *Cf. Trans. Geol. Soc.*, vol. vi, Part I., 2nd ser. 1840, note p. 191. Dr. Bowerbank describes their habit . . . "to unite and form vast masses, which spread over a great extent of surface."

§ Geol. Survey U.S., 9th Annual Report, 1887-8, p. 650.

in the material around. The accretion of this towards centres or areas formed the cherts which help so markedly to build up the scenery of the present earth.

DESCRIPTION OF PLATES XIV AND XV.

The specimens have been taken from the Portland Beds except that represented in Fig. 8.

Photographs of micro-sections. (Magnification about 30 diameters in Figs. 1, 2, 3, 4, 5; and about 50 diameters in Figs. 6, 7, 8.)

Fig. 1 (× 30).—Partly silicified Oolite from Portland Bill. The ground mass is silicified. The calcareous oolite grains have become indented at the margin through silicification at the exterior. Occasionally a chalcedonic granule is included, and in one grain (the lower on the right hand side) comparatively clear dolomite is formed along apparent cracks.

Fig. 2 (× 30).—Chert around nodule from Tillywhin, completely silicified, exhibits the faint outlines of former oolite grains. The ground mass contains numerous circular sections of small sponge spicules.

Fig. 3 (× 30).—Junction of Limestone and chert from quarry at Easton, Isle of Portland. On the left is the Oolitic Limestone which contains sparse granules of chalcedony. The chert to the right encloses a residual fragment of crystalline calcite crossed by cleavage lines, and (below this in the illustration) the calcareous centre of one oolite grain. The others which are completely silicified are only faintly visible.

Fig. 4 (× 30).—Chert band, Winspit, Isle of Purbeck. A transverse section of a Serpula, partly silicified, occurs within a completely silicified ground mass The chalcedony replacing the Serpula wall forms several spherulitic groups; one black cross is seen in the illustration above the central tube, one below, and two to the left of it.

Fig. 5 (× 30).—Chert (with included shell) from west of Tisbury, all completely silicified. The chalcedony along the margin of the shell section exhibits radial structure, and spherulitic along the centre. Coarser spherulitic aggregates occur within the space partly enclosed by the curve of the shell.

Fig. 6 (× 50).—Chert nodule from Winspit completely silicified. (Elsewhere in the slice, parts of Serpulæ occur like that in Fig. 4.) The large sponge spicule (probably *Geodites*) exhibits a wall of coarser granular chalcedony and a canal filled with finer-grained deposit. The sections of smaller spicules crowded in the ground mass are less distinct.

Fig. 7 (× 50).—Chert nodule from Tillywhin. This slice taken from the margin of the nodule (close to the Limestone) shows crowded sponge spicules in longitudinal, transverse, and oblique sections (probably *Pachastrella antiqua*). A little calcite or dolomite occurs in the centre of some spicules and fringing their outer margin.

Fig. 8 (× 50).—Oolitic Limestone partly silicified from inferior Oolite near Frome. Oolitic grains, showing concentric and occasionally radial structure, include single chalcedonic granules formed along concentric zones, or aggregated in the centre. A mosaic mainly of dolomite occurs between the oolite grains.

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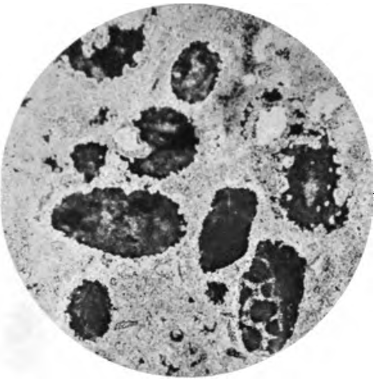

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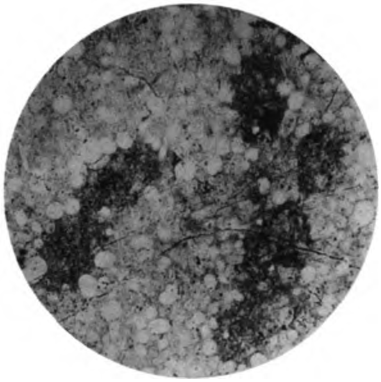

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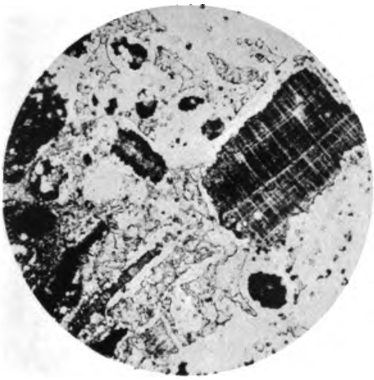

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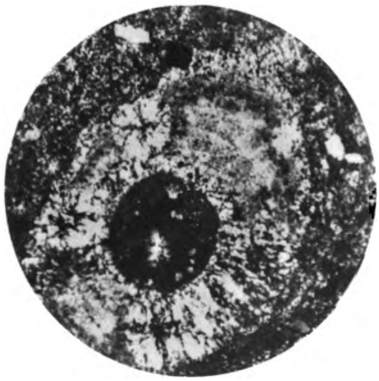

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C. A. Raisin, Photo-micro. *Bemrose Ltd., Collo.*

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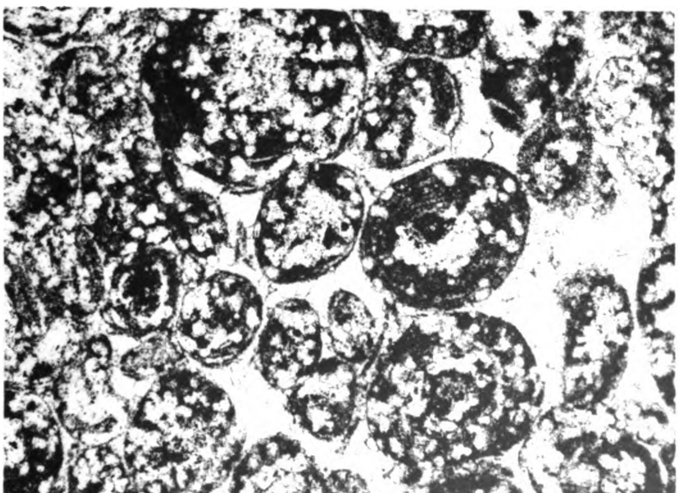

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LIST OF FISH TEETH FROM THE BAGSHOT SANDS (LONDON BASIN).

By A. K. COOMÁRASWÁMY, B.Sc., F.L.S., F.G.S.

(Read December 5th, 1902.)

I HAVE thought it worth while to collect together the various records of the fish teeth which, especially during the last two or three years, have been found in the Bagshot Sands of the London Basin. I am further able to include a small list from a new locality near Brookwood, viz., about a quarter of a mile south-east of the first railway bridge east of Brookwood Station. A deep drainage trench, which runs in a S.W. and N.E. direction, has cut into the middle Bagshot greensand bed. The trench is not new but has been cleared out within the last year or two, and the rainwashed heaps of greensand, though very limited in extent, have yielded a fair number of teeth, for one of which this is the only Bagshot locality. The trench starts about 55 yards from the road and maintains a perfectly straight course for a quarter of a mile; for about two-thirds of this distance the greensand bed is seen, but beyond this point the light-coloured sandy clays which underlie it are exposed. A few chips of lignite were found on the bank near the junction. The beds thus correspond closely to those of the Goldsworth cutting.

The greensand bed has also been exposed this year on Worplesdon Common, in a temporary trench running along the track bordering the common, S.W. and S. of Jordan Hill. The greensand was seen in the trench just east of the pond; it is probably responsible for the bog which also occurs there. No teeth were found. The greensand no doubt occurs at a corresponding level on the farther side of Jordan Hill.

The presence of the bed can be traced at many other points in the neighbourhood of Brookwood and Woking.

I am indebted to Dr. Smith Woodward for kindly determining my own specimens; which are now in the British Museum collection at South Kensington.

The following is a tabulated list of London Basin Middle Bagshot fish remains. It will be seen that the greater number of Prestwich's records are confirmed. Probably many of the gaps will be filled by more extensive collecting.

	Shapley Heath, Winchfield, Prestwich, *Quart. Journ. Geol. Soc.* iii, p. 390.	Goldsworth, Prestwich, *Quart. Journ. Geol. Soc.*, iii, p. 390.	Goldsworth, *Proc. Geol. Assoc.*, xvii, p. 267.‡	Goldsworth, Murton Holmes Collection.‡	Knap Hill Brickfields, Woking, *Proc. Geol. Assoc.*, xv, p. 187.	Brockwood, 400 yards S.E. of Railway Bridge E. of Brookwood.§	Winchfield, *Proc. Geol. Assoc.*, xvi, p. 521.‡	London Clay (… of Britain.)	Bracklesham Beds (… of Britain.)	Barton Clay (… of Britain.)
Carcharodon heterodon, Ag.	×	×	...	...	...	...	...	...	...	...
Carcharodon sp.	...	...	...	×	...	...	...	?	×	×
Odontaspis macrota, Ag. ...	...	×	×	×	...	...	3	?	×	×
Odontaspis elegans, Ag. ...	×	×	×	×	...	6	2	×	×	×
Odontaspis cuspidata, Ag ...	...	...	×	×	...	...	3	?	×	×
Odontaspis acutissima, Ag.	...	...	...	...	...	...	1	...	...	...
Lamna Vincenti, Winkl. ...	...	...	×	...	...	3	3	×	×	×
Lamna sp.	...	...	...	...	×	...	...	...	...	...
Galeocerdo minor, Ag. ...	...	...	...	...	...	...	2	?	...	?
Galeocerdo latidens, Ag. ...	...	..	...	...	...	1	...	...	×	...
Galeocerdo sp.	...	...	×	...	...	...	...	...	...	...
Otodus trigonalis, Jack ...	...	...	?	×	...	...	...	×	×	×
Otodus obliquus, Ag. ...	×	×	...	...	...	...	...	×	×	×
Myliobatis sp.	×	×	×	...	...	16*	8	×	×	×
Aetobatis sp.	×	×	×	...	...	1		×	×	×
Coelorhynchus rectus, Ag...	...	...	...	...	...	...	1†	...	...	...
Edaphodon Bucklandi, Ag.	×	×	...	...	...	...	...	...	...	...
Edaphodon leptognathus, Ag.	×	×	...	...	...	...	...	...	...	...
Vertebrae	×	×	...	...	...	1	2	...	...	...

* And one spine. † A spine. ‡ Determined by Mr. E. T. Newton.
§ Determined by Dr. A. Smith Woodward.

Prestwich's Collection appears to have been lost; the identifications rest on his own authority.

ON THE ZONES OF THE UPPER CHALK IN SUFFOLK.

By A. J. JUKES BROWNE, B.A., F.G.S.

[PLATE XVI.]

(Read March 6th, 1903.)

INTRODUCTION.

HAVING recently been engaged on the preparation of a volume on the Upper Chalk of England for the Geological Survey, I was struck by the very small amount of information about the Upper Chalk of Suffolk which was at my command. This lack of information is no doubt partly due to the fact that the surface of the Chalk is for the most part entirely concealed by a greater or less thickness of Glacial deposits, and is only exposed in some of the valleys, and over small areas in the north-western part of the county. It is, however, more largely due to the lack of interest in the Chalk and its fossils displayed by all geologists, both amateur and professional, who have been connected with the geological investigation of the county. The only two towns actually within the area, Bury St. Edmunds and Sudbury, are small, and though there is a Scientific Society at Ipswich, its members have not until lately paid much attention to the Chalk, ror is there any collection of Chalk fossils in the Ipswich Museum.

It cannot be denied, moreover, that the officers of the Geological Survey failed to avail themselves of their opportunities of obtaining fossils from the numerous exposures which do exist. The whole of Suffolk has been geologically surveyed and explanations of all the maps have been issued, and yet only one of them contains a list of fossils from exposures in the Upper Chalk. This exception is "The Geology of the Neighbourhood of Stowmarket," by Messrs. Whitaker, Bennett, and Blake (1881).

The consequence of this universal neglect was that I found myself without any information that would enable me to zonify the Upper Chalk of Suffolk, or even to identify the existence of any zone except that of *Actinocamax quadratus*, which seemed to be indicated in the memoir above mentioned, and even that was somewhat uncertain.

At the same time it appeared to me that materials for establishing the existence of the other zones ought to be obtainable without much difficulty, and that the zone of *Holaster planus* should be traceable northwards at least as far as the valley of the river Lark, if not as far as the Brandon river. I therefore endeavoured to interest some friends residing in or near Suffolk

in this matter, and asked their assistance in the necessary search for fossils. That I am now able to offer some definite statements about the zones of the Upper Chalk of Suffolk is entirely due to the kind co-operation and activity of my correspondents. My thanks are especially due to Mr. H. Woods of Cambridge, the Rev. E. Hill of Cockfield, Dr. Holden of Sudbury, and Mr. G. H. Hewetson of Ipswich, who have visited such chalk-pits as they could reach, and have sent me the fossils which they were able to obtain. I have also to thank Dr. Wheelton Hind, of Stoke-upon-Trent, who sent for my inspection a small collection which he had obtained some years ago from a quarry at Pakenham, near Ixworth. It will be seen, therefore, that the materials for this paper have been obtained entirely by the gentlemen above mentioned, that I have only acted as palæontogist and as compiler of the notes with which they have furnished me.

STRATIGRAPHY.

Zone of Holaster planus.—This zone, where the Chalk-Rock is developed, has that rock at its base, and is now regarded as the lowest member of the Upper Chalk in England. It appears to enter Suffolk a little west of Dalham. Mr. H. Woods has found the Chalk-Rock well exposed in a quarry at Wood Ditton in Cambridgeshire, and the higher beds, consisting of firm, white chalk with flints, in a quarry half-a-mile north of Chieveley, whence he obtained *Micraster cor-bovis* and *M. præcursor*. The Chalk-Rock he found again in a pit about a quarter-of-a-mile west of Upper Higham (in Suffolk); while the upper beds he recognised in the railway-cutting east of Higham Station, and in an adjacent pit by the main road to Bury; from these exposures Mr. Woods obtained *Holaster placenta* and some Micrasters which were sent to Dr. Rowe, who considers them to be forms characteristic of the upper part of the zone of *Holaster planus*.

From Higham the outcrop of the zone probably passes north-eastward to the valley of the Lark near Lackford, but no one has yet explored that district, nor is its further course yet known, but it must pass to the east of Icklingham and thence northward to, or a little east of, Wangford.

Zone of Micraster cor-testudinarium.—This zone has not yet been definitely recognised between Buckinghamshire and Norfolk, though there is no reason to doubt its continuity. Quarries and cuttings are not lacking in places where the zone is likely to be exposed in the counties of Hertford, Essex, and Suffolk, but they have not yet received special attention, and few fossils from them have come into the hands of zonal experts. This zone, moreover, is not a well-marked one; it has no lithological

peculiarity, and its fauna differs little from that of *Holaster planus*, though Dr. Rowe has shown that where a sufficient number of Micrasters can be collected it can be recognised by their varietal characters.

Its outcrop probably enters Suffolk near Lidgate, and should be looked for near the villages of Ouseden, Denham, Great and Little Saxham, Risby, and Hengrave.

Mr. H. Woods visited the Parkhouse chalk-pit, north of Lidgate, in 1899, and found an exposure of—

	Feet.
Well-bedded chalk with flints ... ... about	18
Layer of continuous tabular flint (1 to 2 inches)	
Soft-jointed chalk with many flints and fragments of *Inoceramus*	9

This chalk probably belongs to the zone of *M. cor-testudinarium*, though the only fossils found were an *Inoceramus* and a crushed *Terebratula.*

Mr. Woods has also examined a small pit south-east of "Great Plantation," near Little Saxham, and writes that it shows about 14 feet of soft, white chalk with a few flints; it contains many fragments (often large) of *Inoceramus* and spines of *Cidaris clavigera.* Although these fossils are not enough to determine the zone, it is a fact that *C. clavigera* is especially abundant in the zone of *M. cor-testudinarium* throughout the southern counties from Devon to Sussex, and that fragments of *Inoceramus involutus* and other large species are also common in it.

The chalk near Brandon, which was formerly so largely quarried to obtain flints for the making of gun-flints, must belong either to this zone or to the lowest part of the *M. cor-anguinum* zone. No fossils except *Echinocorys scutatus* have yet been recorded from it.

Zone of Micraster cor-anguinum.—This zone underlies the north of Essex to the east of Saffron Walden, and passes into Suffolk by Haverhill, Clare and Long Melford, but exposures are few and small owing to the prevalent mantle of Glacial drift. Towards Bury St. Edmunds, however, this mantle has been partially removed, and tracts of bare chalk appear in which quarries have been opened here and there. It was not, however, till recently that fossils from any of them came into my hands. Last summer the Rev. E. Hill, acting on a suggestion from me, visited a quarry at Bury (south-west of the town), and obtained fossils which proved the chalk of Bury to belong to the *cor-anguinum* zone.

Mr. Hill informs me that the quarry is about 35 ft. deep, the lower 20 ft. being without flints and the upper part containing two layers of flints and a few scattered flints. The following were the fossils obtained :—

Echinocorys scutatus, Leske.	*Thecidium Wetherelli.*
Micraster cor-anguinum, Leske.	*Ostrea vesicularis*, Sow.
„ „ var.	*Plicatula sigillina*, Woodw.
Terebratula semiglobosa, Sow.	*Serpula sp.*

The echinoderms were submitted to Dr. Rowe, who informs me that they belong to varieties which are characteristic of the middle part of the zone of *M. cor-anguinum.* Some of the Micrasters are short, gibbous and conical, strongly resembling *Epiaster gibbus*, except that they possess a subanal fasciole. Dr. Rowe regards these as merely a variety of *M. cor-anguinum*, but M. Lambert includes them in his *M. senonensis*, a species based on the forms without a fasciole, and generally known as *Epiaster gibbus* (*Wright*, non *Lam.*).

Dr. Wheelton Hind, of Stoke-upon-Trent, has kindly allowed me to examine some fossils which he obtained some years ago from a chalk pit at Pakenham, a village 4½ miles E.N.E. of Bury. Among these I identified the following species, which show that this locality comes within the same zone:—

Echinocorys scutatus, Leske.	*Spondylus spinosus*, Sow.
Micraster cor-anguinum, Leske.	„ *latus*, Sow.
Epiaster gibbus, Wright.	*Plicatula sigillina*, Woodw.
Galerites albogalerus, Leske.	*Thecidium Wetherelli.*

About 1½ miles N.E. of Pakenham, and the same distance S.E. of Ixworth, is a quarry which Mr. Hill last visited, and of which he gives me the following account:—"This is an extensive but shallow excavation, usually only 10 feet deep, but sometimes worked to 14 feet; from it caves are tunnelled into the chalk, and one of these is 30 feet in length. The chalk is very white and soft, and there are a few flints scattered irregularly through it, with a layer of flints about 10 feet from the surface, some of the latter being large and up to 2 feet in length." Mr. Hill found a few fossils, but the Echinoderms are much crushed, and I am indebted to Dr. Rowe for assistance in their determination. They appear to be

Micraster cor-anguinum, Leske,	*Ostrea vesicularis*, Sow.,
Galerites albogalerus? (Young),	*Inoceramus* (fragments),
Cidaris sceptrifera, Mant.,	*Kingena lima*, Defr.,
Scalpellum maximum, Darw.,	*Ventriculites radiatus*, Mant.

This chalk probably belongs to the highest part of the zone.

The chalk of Thetford is known to belong to the zone of *M. cor-anguinum*, so that there can be no doubt that the lower part of this zone comes in between Thetford and Brandon, but no one has yet explored that area for fossils.

Zone of Marsupites. Thanks to the kind assistance of Dr. Holden and Rev. E. Hill, the existence and location of this zone has been ascertained in the South of Suffolk. Plates of

Uintacrinus have not yet been found, but there is good reason to believe that the chalk which is quarried at Sudbury belongs to the band or sub-zone which is characterised by this genus. There are several large quarries here, exposing soft white chalk with very few flints. One of them to the north-east of the town is worked to a depth of 50 feet, and from this Dr. Holden obtained some fossils which he sent to me. The species proved to be the following:

Lamna appendiculata, Ag.,	*Ostrea vesicularis*, Sow.,
Oxyrhina sp.,	„ *semiplana*,
Actinocamax granulatus, Blainv.,	*Pecten cretosus*, Defr.,
„ *verus*, Miller,	*Lima Hoperi*, Sow.

Noticing that the specimen of *Act. granulatus* was granulated, but somewhat feebly and scantily, I sent it and the *Act. verus* to Dr. Rowe, who has recently made a study of these and the other species of the genus, asking him if their characters suggested a definite zonal horizon. He replies: "The example of *A. granulatus* in no way suggests the zone of *M. cor-anguinum*, for I have yet to see an *Actinocamax* with granulated guard from this zone. On the other hand, the scanty granulation resembles that on specimens from the zone of *Marsupites*, though few have yet been found in the *Uintacrinus* band. *A. verus*, on the other hand, is a common fossil in the *Uintacrinus* band, and the example sent is similar to those I have from that horizon. You will gather, therefore, that I consider your view of *Marsupites* zone, and probably *Uintacrinus* band, will turn out to be the correct interpretation."

This determination finds confirmation in the discovery of a plate of *Marsupites* at Monks Eleigh, a village about 7 miles N.E. of Sudbury. The quarry is one of many visited by Mr. E. Hill, and among the few fossils which he obtained from it there was an unmistakable plate of *Marsupites testudinarius*, the first that has been discovered in Suffolk. By this the position of the *Marsupites* band in the south of Suffolk is definitely located, and Mr. Hill sends me the following particulars of the chalk pit from which it was obtained: "The pit is in 'Back Lane' on the south side of the brook; it has a face of about 8 ft. high and 20 ft. long, and the chalk is soft, white, and damp: the only flints visible were one or two isolated nodules." Fossils are scarce, and the only organisms found beside the plate of *Marsupites* were a small *Ostrea*, fragments of *Inoceramus* shell, and *Porosphæra globularis*.

From Monks Eleigh and Brent Eleigh (near Lavenham) the outcrop of this zone probably runs northward by Preston, Brettenham, Felsham, and Elmswell, but this district is deeply covered with Glacial deposits, so that no evidence is obtainable. Further north, however, the Chalk comes to the surface again in

some places, and has been quarried near Wattisfield and Botesdale. No fossils, however, have yet been recorded from these pits, and the only information I have been able to obtain is that published in the "Geological Survey Memoir" on the country round Diss, Eye, &c. (explanation of Sheet 50, N.W.). The chalk exposed near Wattisfield, Rickinghall, and Botesdale is therein described as soft and marly with few flints, and I feel confident that it will prove to belong either to the zone of *Marsupites* or to the lower part of the zone of *Actinocamax quadratus*.

Zone of Actinocamax quadratus.—In the south east of England (Kent and Sussex) the thickness of the chalk which contains *Marsupites* is only from 50 to 60 ft., and it is not likely to be much more in Suffolk, so that we might look for the overlying zone to come in not far to the east of Monks Eleigh. An exposure presents itself about 2 miles east of that place and near the village of Nedging; from this Mr. Hill was fortunate enough to obtain a specimen of *Actinocamax granulatus*, which is well granulated and has a fairly deep alveolus, thus resembling the specimens which occur in the zone of *Act. quadratus*. Mr. Hill tells me that the pit is only 20 ft. deep, and that no flints were visible in the exposed face, though a few were lying on the floor: no other fossils could be found except small fragments of shell.

In the valley of the Gipping, between Needham Market and Ipswich, there are several large chalk pits, all of which are in the zone of *Actinocamax quadratus*. One of these is a little south of Needham Market, and is known as Barking chalk pit. The following fossils were obtained from it by Mr. J. H. Blake, and are recorded in the Survey Memoir on the "Neighbourhood of Stowmarket," *Actinocamax granulatus*,* *Ostrea acutirostus*, *Inoceramus mytiloides ?* *Inoc. sp.* and a Bryozoon.

Lower down the valley there is a large pit at Claydon where 50 ft. of chalk is sometimes shown, and Mr. Whitaker in the memoir above cited has described it as almost flintless. The only fossil recorded by him was "a small *Ostrea*, as at Needham Market" (probably *O. acutirostus*), but Mr. G. H. Hewetson, of Ipswich, has sent me three others for identification, which prove to be *Echinocorys scutatus*, *Cidaris hirudo ?* (plate), and *Coscinopora quincuncialis*.

About two miles further south at Bramford is another quarry from which a larger number of fossils have been obtained. Mr. Hewetson informs me that the pit is a large one, and on its eastern side presents a face of about 130 feet in height; the chalk is white, where not stained yellow by infiltrated oxide of iron, it is soft but firm, and without flints except for one layer of flint-nodules about 110 feet from the surface. The fossils

* Recorded as *Bel. quadrata*, but Mr. E. T. Newton informs me that the specimen is an *Act. granulatus*.

which have been obtained from this quarry by the members of the Ipswich Scientific Society were sent to me for identification, and included the following species:

Lamna appendiculata, Ag.,	*Spondylus latus*, Sow.,
Belemnitella lanceolata, Blainv,	*Inoceramus* (fragment),
Actinocamax granulatus, Blainv,	*Serpula*, sp.,
Ostrea curvirostris, Nilss,	*Echinocorys scutatus*, Leske,
,, *normaniana*, d'Orb.,	*Offaster pilula*, Lam.,
,, *vesicularis*, Sow.,	*Cœlosmilia granulata*, Dunc.

This assemblage is sufficient to prove that the chalk of Bramford belongs to the zone of *Act. quadratus*.

Zone of Belemnitella mucronata.—This zone has not yet been recognised in Suffolk. There can be little doubt that it underlies the Eocene deposits of the eastern part of the county, and it is just possible that it comes near the surface to the north of Ipswich and to the east of Debenham, by Otley, the Sohams, and Southolt. Owing, however, to the covering of Drift, the only locality where chalk is actually exposed in this area is near Earl Soham, where one or two old chalk-pits were noticed by Mr. W. H. Dalton.* A search in these old pits, and in chalk brought up from wells sunk in that neighbourhood, might furnish proof of the existence of this zone.

Conclusions.—The observations and fossils above recorded fall far short of being a complete account of the zones of the Upper Chalk in Suffolk, for they include but little information about the northern part of the county. They are, however, sufficient to establish the usual sequence of zones in the southern part from that of *Holaster planus* to an horizon that must be high up in that of *Act. quadratus*.

Moreover, they demonstrate another important fact, namely, the complete unconformity of the Eocene to the Chalk. Between Bishops Stortford and Ipswich, the boundary of the Reading Beds, as drawn on the maps of the Geological Survey, is roughly east and west, more accurately about E. 20 N. by W. 20 S., while the zones of the Upper Chalk appear to run nearly north and south (see map, Pl. xvi). We know that such is the direction of their strike in Norfolk, and in all probability it is continued southward through the greater part of Suffolk, only changing to a S.W. direction in the south-western portion of the county.

From the position of the zone of *Marsupites* at Sudbury and Monks Eleigh, and from the coming in of the *A. quadratus* zone further east, it is clear that these zones emerge in this neighbourhood from beneath the transgressive Eocene boundary, and they

* See "The Geology of the Country round Aldborough, Framlingham, etc.," *Mem. Geol. Survey*, 1886, p. 3.

must thence pursue a northerly course in order to meet the southward continuation of their known outcrops in Norfolk.

I have therefore ventured to show the probable courses of the zones of the Upper Chalk on the accompanying map (Pl. xvi), but it must be remembered that the evidence is at present too scanty for this to be regarded as an accurate delineation of the zones: it is only a sketch map, designed to show the general course which I believe them to take, and to bring out the fact of the great break and unconformity between the Chalk and the Eocene.

The following is a list of the fossils which have been obtained by my correspondents from the chalk pits mentioned in this paper. I have included the fossils from pits in the zone of *Holaster planus*, which are really in Cambridgeshire, but have distinguished them by the letter C, while S indicates those which have been found in Suffolk. Though the column assigned to the zone of *M. cor-testudinarium* contains only two entries, it will serve to show those who are interested in the subject where further exploration is specially required.

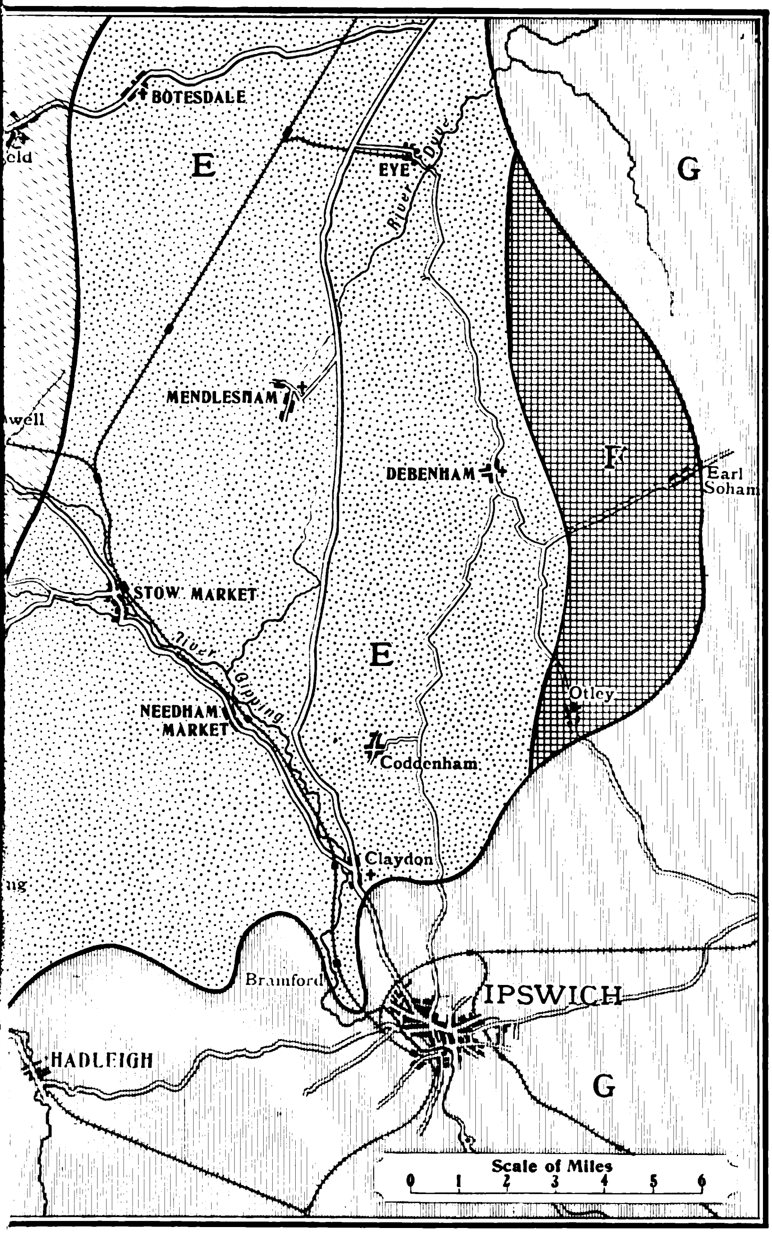
	Zone of *Holaster planus.*	Zone of *Micr. cor-testudinarium.*	Zone of *Micr. cor-anguinum.*	Zone of *Marsupites.*	Zone of *Act. quadratus.*
PISCES.					
Cimolichthys lewesiensis, Leidy.	...	...	S	...	...
Lamna appendiculata, Ag.	...	...	...	S	S
Oxyrhina sp.	...	...	...	S	...
Protosphyræna ferox, Leidy.	...	...	...	...	...
CEPHALOPODA.					
Pachydiscus peramplus, Mant.	C	...	...	...	...
Crioceras ellipticum, Mant.	C	...	...	...	...
Scaphites Geinitzi, d'Orb.	C	...	...	...	...
Nautilus sublævigatus, d'Orb.	C	...	...	...	...
Actinocamax granulatus, Blainv. ...	...	...	...	S	S
Actinocamax verus, Miller	...	...	...	S	...
Belemnitella lanceolata, Blainv.	...	...	...	...	S
GASTEROPODA.					
Avellana Humboldti, Müller	C	...	...	...	...
Natica vulgaris, Reuss	C	...	...	...	...
Pleurotomaria perspectiva, Mant. ...	C	...	...	...	...
Solariella gemmata, Sow....	C	...	...	...	...
Trochus cirrus, Sow.	...	...	S	...	...
Trochus Schlüteri, Woods	C	...	...	...	...
LAMELLIBRANCHIA.					
Avicula sp.	...	...	...	...	S
Cardita cancellata, Woods	C	...	...	...	...

	Zone of *Holaster planus.*	Zone of *Micr. cor-testudinarium.*	Zone of *Micr. cor-anguinum.*	Zone of *Marsupites.*	Zone of *Act. quadratus.*
Inoceramus Cuvieri, Sow...	C	...	...	...	...
Inoceramus cf. mytiloides, Sow.	...	...	...	...	S
Inoceramus sp. (small)	C	...	...	...	...
Inoceramus sp. (large)	...	S	...	S	...
Lima Hoperi, Sow.	C	...	...	S	...
Ostrea acutirostris, Nilss.	...	...	...	...	S
Ostrea curvirostris, Nilss...	...	...	...	...	S
Ostrea hippopodium, d'Orb.	C	...	...	...	...
Ostrea normaniana, d'Orb.	...	...	...	...	S
Ostrea semiplana, Sow.	C	...	...	S	S
Ostrea vesicularis, Sow.	...	...	S	S	S
Pecten cretosus, Defr.	...	...	...	S	...
Pinna decussata, Goldf.	C	...	...	...	...
Plicatula sigillina, Woodw.	C	...	S	...	...
Septifer lineatus, Sow.	C	...	...		...
Spondylus latus, Sow.	C	...	S	...	S
Spondylus spinosus, Sow....	C S	...	S	...	...
BRACHIOPODA.					
Kingena lima, Defr.	...	...	S	...	...
Rhynchonella plicatilis, Sow.	C	...	...	...	...
Rhynchonella reedensis, Eth.	C	...	...	...	...
Terebratula carnea, Sow....	C	...	...	...	...
Terebratula semiglobosa, Sow.	C S	...	S	...	S
Terebratulina gracilis, Schloth. (var.) ...	C	...	...	...	...
Terebratulina striata, Wahl.	C	...	...	...	...
Thecidium Wetherelli, Dav.	...	...	S	...	...
BRYOZOA.					
Diastopora congesta, d'Orb.	C	...	..	...	...
Domopora clavula (?), d'Orb.	C	...	...	...	...
Membranipora sp....	C	...	...	...	...
Retepora (?)	...	...	...	...	S
CRUSTACEA.					
Scalpellum maximum, Darw.	...	...	S	...	...
ANNELIDA.					
Serpula sp. (nautiloid)	...	...	S	...	...
Serpula sp. (five-angled)...	...	...	...	...	S
ECHINODERMA.					
Bourgueticrinus ellipticus, Müller ...	...	...	S	...	...
Bourgueticrinus sp. (cylindrical) ...	...	...	...	S	S
Cidaris clavigera, Kœnig...	...	S	...	...	...
Cidaris sceptrifera, Mant.	C	...	S	...	...
Cidaris serrifera, Forbes...	...	...	S	...	...
Cidaris vesiculosa, Goldf.	C	...	...	...	...

	Zone of *Holaster planus.*	Zone of *Micr. cor-testudinarium.*	Zone of *Micr. cor-anguinum.*	Zone of *Marsupites.*
Cyphosoma radiatum, Sorig.	c	...	...	...
Echinocorys scutatus, Leske	c	...	s	...
Epiaster gibbus, Lam.	...	...	s	...
Galerites albogalerus, Leske	...	...	s	...
Holaster planus, Mant.	c s	...	...	...
Holaster placenta, Ag.	s	...	...	...
Infulaster excentricus, Rose	...	...	c	...
Marsupites testudinarius, Schloth ...	...	...	...	s
Micraster cor-anguinum, Leske	..	...	s	...
Micraster cor-anguinum var. gibbosa ...	...	...	s	...
Micraster cor-bovis, Forbes	c s	...	...	...
Micraster Leskei, Desm.	c	...	...	...
Micraster præcursor, Rowe	c s	...	s	...
Offaster pilula, Lam.	...	...	...	...
ACTINOZOA.				
Cœlosmilia granulata, Dunc.	...	...	...	...
Parasmilia centralis, Mant.	...	...	s	...
SPONGIDA.				
Coscinopora quincuncialis, Smith... ...	c	...	...	...
Porosphæra globularis, Phil.	c	...	...	s
Ventriculites radiatus, Mant.	...	...	s	...

INDEX TO MAP. (Plate XVI.)

G. Chalk covered by Tertiary Beds.
F. Zone of *Belemnitella mucronata* (uncertain).
E. Zone of *Actinocamax quadratus.*
D. Zone of *Marsupites testudinarius.*
C. Zone of *Micraster cor-anguinum.*
B. Zones of *Micraster cor-testudinarium* and of *Holaster planus.*
A. Middle and Lower Chalk.



ALK IN SUFFOLK.

.G.S.

ORDINARY MEETING.

FRIDAY, NOVEMBER 7TH, 1902.

H. W. MONCKTON, F.L.S., F.G.S., President, in the Chair.

The following were elected members of the Association: William Chandler Block, H. W. Cadoux, Thomas Davies Jones.

The evening was then devoted to a Conversazione, and the following is a list of the exhibitors and their exhibits:

THE PRESIDENT: Specimens and Photographs relating to the Excursions of 1902.

THE DIRECTOR OF THE GEOLOGICAL SURVEY: New Colour-Printed Geological Maps recently published by the Geological Survey.

DR. G. ABBOTT: Concretions from the Magnesian Limestone of Sunderland, and flint implements from Tunbridge Wells.

HENRY BASSETT, B.SC.: Fossils from the Oldhaven Beds at Sundridge Park Tunnel, Kent, and a small Ichthyosaurus from the Lower Lias, near Stratford-on-Avon.

MISS CAROLINE BIRLEY: Cretaceous and Tertiary fish teeth, etc., from foreign localities.

REV. J. F. BLAKE, M.A., F.G.S.: Examples of contortion in rocks.

G. F. BROWN: Chalk fossils from Brighton and Merstham cutting.

REV. R. ASHINGTON BULLEN, B.A., F.G.S.: Polished slabs of Ichthyosaurus and Plesiosaurus bones from Lyme Regis; polished flints, &c., from Southwold and Harwich; eoliths from Alderbury and the Plateau terrace of the West bank of the Avon, Hants; teeth of *Elephas meridionalis* and associated eoliths from Dewlish and Cromer; implements of shell and slate, &c., from Harlyn Bay and Constantine Island; implements of flint and obsidian from Mexico, and of quartzite and chalcedony from Khami ruins, near Bulawayo (lent by Prof. T. Rupert Jones); *Hygromia montivaga*, West, from Harlyn Bay (Proc. Malac. Soc., 1902, pp. 185-8).

G. E. DIBLEY, F.G.S.: A series of specimens illustrating the variation in *Echinoconus conicus*; a fine specimen of *Cidaris clavigera* from Northfleet; and other fossils from the *Micraster cor-anguinum*, *Holaster planus* and *H. sub-globosus* zones.

ROBERT ELLIOTT: Flint implements from various countries.

PERCY EMARY, F.G.S. (on behalf of Mr. A. B. F. Wilson, of Geelong, Victoria): A collection of Eocene fossils from Victoria.

A. S. FOORD: A series of facsimile models of stone implements, illustrating the methods of affixing handles, &c., based on authentic specimens in the museums of Europe and America.

JAMES FRANCIS: Specimens of geyserite and lavas from Iceland.

J. W. GARNHAM: A series of Indian jade and other carved oriental stones.

W. F. GWINNELL, B.Sc., F.G.S.: Jaw of a labyrinthodon (*Loxomma almani*, Huxley) from the Lower Limestone Shale, Gilmerton, near Edinburgh; volcanic bomb from St. Vincent; rocks from North Wales; Triassic sandstones showing wave-ripples, rain-pittings, and sun-cracks; forms of quartz; and a new geological map of the British Isles.

F. W. HARMER, F.G.S.: Red Crag fossils (Waltonian) from Little Oakley, Suffolk.

W. MURTON HOLMES: Sponges, echinodermata, brachiopoda, bryozoa, ostrea, fish teeth, &c., from the Lower Greensand of Faringdon, Berks.

MISS M. S. JOHNSTON: Rocks, photographs, &c., from New Zealand.

HENRY KIDNER: Specimen of asbestos from Nant Francon Pass, North Wales.

A. LE GRAND: Sections of well borings at New Lodge, Windsor Forest, Ingatestone, and Ilford; and several cores from other borings.

P. A. B. MARTIN: Eoliths from Kent plateau.

F. W. RUDLER, F.G.S.: Photographs illustrating the volcanic eruptions in St. Vincent, West Indies, 1902; and the great eruption of Etna, 1892. (The photographs of St. Vincent taken by Mr. J. C. Wilson, Kingstown.)

A. E. SALTER, B.Sc., F.G.S.: Igneous and other erratics from the Drifts of the Midland Counties.

WILLIAM SEMMONS: A series of specimens illustrating crystal enclosures—moving bubbles, foreign materials, lines of growth, etc.

W. P. D. STEBBING, F.G.S.: The Association's Album of photographs.

F. ROSS THOMSON, F.G.S.: Microscopic slides of bryozoa from the Coralline Crag, Suffolk, collected during the Long Excursion.

JOHN THRUSSELL: Rocks, etc., from the Island of Arran, N.B., and specimens of volcanic dusts.

S. HAZZLEDINE WARREN, F.G.S.: Rude palæolithic implements approaching a "prepared core" in form, from the valley of the Western Yar, Isle of Wight, and from the valley of the river Lea; a Prepared Core from Pressigny-le-Grand for comparison with the preceding; Palæolithic flakes from the Western Yar, Isle of Wight; and Neolithic flakes from the Sussex Downs, probably struck from similar cores.

E. WESTLAKE, F.G.S.: Eoliths from West Hampshire.

GILBERT WHITE: Human skull from the Middle Terrace Brick-Earth of Swanscombe, Kent (? Pleistocene); and bones and antlers of *Cervus* from the forest bed.

W. H. WICKES: Photograph, taken by Mr. J. W. Tucker of Bristol, of a weathered slab of the Rhætic Bone Bed from Garden Cliff, Gloucestershire, with saurian and fish bones, teeth, scales, and coprolites—encrusted with iron pyrites.

ANNUAL GENERAL MEETING.

FRIDAY, FEBRUARY 6TH, 1903.

H. W. MONCKTON, F.L.S., F.G.S., President, in the Chair.

Messrs. H. Bassett and M. A. C. Hinton were appointed Scrutineers of the ballot.

The following report of the Council for the year 1902, was then read:

THE numerical strength of the Association on December 31st, 1902, was as follows:

Honorary Members	16
Ordinary Members—	
a. Life Members (compounded)	162
b. Old Country Members (5s. Annual Subscription)	4
c. Other Members (10s. Annual Subscription) .	416
Total	598

This shows a net increase of eighteen as compared with the corresponding figures for the previous year.

During the year forty-three new members were elected.

The Council regret to record the death of one of the founders of the Association, the Rev. Thomas Wiltshire.

It was on the 2nd of December, 1858, that six gentlemen met at the Working Men's College in Great Ormond Street, and decided upon the name, The Geologists' Association. Mr. Wiltshire was one of the six, and he was almost the first President, for Toulmin Smith, who was actually the first, and presided at the first Ordinary Meeting on January 11th, 1859, resigned after a few weeks, and was succeeded by Professor Wiltshire, who served as President until 1862.

In 1871 he was again elected President, and with the exception of John Morris is the only member who has served as President for two distinct terms. His first paper as a geologist, namely, that on "The Red Chalk of England," was published by the Association in 1859. This paper was a notable contribution to knowledge, and still remains of great value. Professor Wiltshire always took the greatest interest in the welfare of the Association, and until quite recently was one of its Trustees.

GEOLOGISTS' ASSOCIATION.

Dr. **Income and Expenditure for the Year ending Dec. 31st, 1902.** **Cr.**

	£	s.	d.
To Balance from 1901	136	5	5
„ Life Compositions	35	5	0
„ Admission Fees	20	0	0
„ Annual Subscriptions	198	16	6
„ Dividends on Nottingham Corporation Stock ...	31	3	8
„ Sale of Publications	10	19	8
„ Sale of "Record"	3	15	6
„ Sale of "Paris Basin"	0	10	10
„ Special Donations for Publications:			
For Auvergne Papers per Dr. Cullis ...	11	16	0
For Crag Pamphlet from F. W. Harmer, Esq.	7	8	5
	£456	1	0

	£	s.	d.
By Printing "Proceedings"	130	12	6
„ „ Monthly Circulars	14	15	3
„ Miscellaneous Printing	11	12	6
„ Illustrating "Proceedings" and Circulars ...	32	16	1
„ Postage, Telegrams and Messages	39	16	3
„ Addressing	6	3	0
„ Library (including Honorarium to Librarian of St. Martin's Library)	8	16	8
„ Attendance, Lighting, Lantern, etc., at Evening Meetings	18	0	0
„ Excursions	9	15	4
„ Insurance	2	15	0
„ Stationery	6	2	2
„ Miscellaneous Expenses	1	11	2
„ Purchase of £74 17s. 6d. Nottingham Corporation Stock, and Broker's Commission ...	75	0	0
„ Balance at Bank of England, Dec. 31st, 1902	98	5	1
	£456	1	0

We have compared the above account with the vouchers, and find it correct.
We have also verified the investment of £1,108 14s. 5d. Nottingham Corporation Stock.

January 19th, 1903.

F. L. KITCHIN }
G. E. DIBLEY } *Auditors.*

The financial position of the Association continues satisfactory. The ordinary income in 1902 was £300 11s. 2d., or about £16 less than in 1901. The decrease occurs under the heads of Life Compositions, Admission Fees, and Annual Subscriptions. Leaving out of account the Life Compositions—which must be uncertain in amount from year to year—the decrease is but a little over £10, and £6 10s. of this falls under the head of Admission Fees, so that the whole decrease is really due to a falling off in the payments from new members.

The expenditure for the year, as shown in the statement, was £282 15s. 11d., which is £41 6s. 1d. more than that shown for the previous year. The present statement, however, includes an item of £27 6s. 5d. for printing in 1901, and there are now no bills outstanding for 1902, so that the actual expenditure in 1902 was about £13 less than that for the previous year. The balance in hand at the end of the year was £98 5s. 1d. It would have been considerably smaller but for the generous contribution from F. W. Harmer, Esq., towards the cost of the Long Excursion Pamphlet, and the special donations, kindly collected by Dr. Cullis towards the cost of illustrating the Auvergne papers. From the balance in hand the Council have decided to set apart a sum of £35—representing the value of the Life Compositions received during the year. It will not be necessary to invest this amount because, of the money invested last year, £35 was set apart as balance of the Royal Society's grant towards the cost of the parts of Dr. Rowe's work, which are yet to be published. This £35 will now be considered as part of the ordinary investments of the Association and the corresponding amount in the current balance will be available towards the cost of the further instalment of Dr. Rowe's papers, which it is hoped will be issued in the course of the current year.

The PROCEEDINGS for the year have been issued in three parts, which complete the seventeenth volume. They comprise some two hundred and twenty pages of text, forty figures, and nine plates.

The thanks of the Association are due to the several authors for their communications.

The Association is also indebted to several members, who by subscriptions, have rendered it possible to illustrate the numbers issued in a more than usually satisfactory manner. In this connection Prof. H. E. Armstrong, Prof. J. W. Carr, Mr. A. K. Coomáraswámy, Lieut. G. E. Coke, Messrs. E. E. L. Dixon, A. Farrar, H. A. Hinton, T. V. Holmes, Dr. E. Johnson, Miss L. Jebb, Dr. H. C. March, Messrs. P. A. B. Martin, F. Meeson, F. Nichols, J. Parker, Dr. E. W. Skeats, Messrs. E. W. Small, W. P. D. Stebbing, F. Trickett, and W. H. Whitaker must be mentioned, who contributed towards the expenses of illustrating the Report of the Auvergne excursion. To MM. J. Giraud, Ph.

Glangeaud, and Pierre Marty, thanks are due for a large part of the text of that Report, and for the originals from which the plates and figures were prepared. Professor H. E. Armstrong and Prof. W. W. Watts are to be thanked for the collotype plate, illustrating the Report of the excursion to Charnwood Forest; and to Mr. F. W. Harmer the members are especially indebted, not only for his "Sketch of the Later Tertiary History of East Anglia," but also, as already mentioned, for defraying a considerable proportion of the expenses involved in the illustration and publication of that most admirable paper.

The loan of various blocks and the permission to obtain and employ certain clichés are due to the courtesy of the Council of the Geological Society and the Editors of the "Geological Magazine."

The additions to the Library during the year have been numerous and valuable, and consist not only of the usual series of publications of other societies and institutions, but also of works received from private persons as gifts or in exchange.

The Library having now outgrown the accommodation that can be given to it at St. Martin's Public Library, an increasing number of books has perforce accumulated at Gower Street, where, under present conditions, they are of restricted use to members. In these circumstances the Council have had much pleasure in accepting a proposal, made by the authorities of University College, that the whole of the Association's Library should be deposited at University College. The Library will there be available to members under very favourable conditions, and the use of the College Science Library will also be granted to members, certain privileges being given in return by the Association to those entitled to use the College Libraries. It is expected that the necessary preparations at Gower Street will shortly be completed, and that the whole of the Library will be available for use in a few months from the present time.

The conditions under which books can be referred to and borrowed by members will be announced in due time.

The following is a list of the papers read at the evening meetings:

"A Dozen Years of London Geology," being the address of the retiring President, W. WHITAKER, B.A., F.R.S.

"The Zones of the White Chalk of the English Coast: III—Devonshire," by Dr. A. W. ROWE, F.G.S.

"On a Peculiarity in the Course of Certain Streams in the London and Hampshire Basins," by H. J. OSBORNE WHITE, F.G.S.

"Note on the Occurrence of *Microtus intermedius* in the Pleistocene Deposits of the Thames Valley," by MARTIN A. C. HINTON and GILBERT WHITE.

"A Sketch of the Later Tertiary History of the Eastern Portion of East Anglia," by F. W. HARMER, F.G.S.

"On the Formation of Chert," by Miss CATHERINE A. RAISIN, D.Sc.

"A List of the Fish Remains from the Middle Bagshot Beds of the London Basin," by A. K. COOMÁRASWÁMY, B.Sc., F.G.S.

Lectures were delivered by VAUGHAN CORNISH, D.Sc., F.G S., F.C.S., F.R.G.S on "The Waves of Sand and Snow"; by Prof. H. A. MIERS, M.A., F.R.S., on "Klondike, its Geology and Mining"; and by Prof. W. W. WATTS, M.A., Sec. G.S, on "The Geology of Charnwood Forest."

The thanks of the Association are due to all of these.

A well-attended Conversazione was held in November, and a full list of the exhibits will be published in the PROCEEDINGS. Thanks are due to the many members who contributed to the success of that evening.

During the past season the following Museum visits and excursions have been successfully carried out.

DATE.	PLACE.	DIRECTORS.
March 15, 1902	Natural History Museum, Cromwell Road, S.W.	Dr. Arthur Smith Woodward, F.R.S., and Col. C. K. Bushe, F.G.S.
Mar. 28 to April 2 (Easter)	The Gower Peninsula, South Wales	R. H. Tiddeman, M.A., F.G.S.
April 12	Zoological Society's Gardens, Regent's Park	F. E. Beddard, M A., F.R.S.
April 26	S.E.R. Main line widening, Elmstead Cutting, and Chiselhurst Caves	T. V. Holmes, F.G.S., and C. W. Osman, A.M.I C.E.
May 3	Chesham	Upfield Green, F.G.S.
May 10	Guildford and Godalming	A. K. Coomáraswámy, B.Sc., F.G S.
May 17 to 20 (Whitsuntide)	Charnwood Forest	Prof. W. W. Watts, M.A., Sec. G.S., and C. Fox Strangways, F.G.S.
May 31	Reading	O. A. Shrubsole, F.G.S., and W. Whitaker, B.A., F.R.S.
June 7	Headington, Shotover, and Wheatley	Rev. J F. Blake, M.A., F G S.
June 14	Brockham, Reigate, and Redhill	W. P. D. Stebbing, F G.S, and W. Whitaker, B.A., F.R.S.
June 21	Kintbury, Inkpen, and Woodhay	H. J. Osborne White, F.G.S.
July 5	Ayot and Welwyn	J. Hopkinson. F.G.S., A.Inst.C.E., and A. E. Salter, B Sc., F.G.S.
July 12	Frindsbury and Upnor	W.Whitaker,B A.,F.R.S., and C. Bird, B.A.,F.G.S.
July 26 to Aug. 4 (Long Excursion)	Suffolk and Norfolk	W. Whitaker, B.A., and F. W. Harmer, F.G.S.
October 4	S. E. R. Main Line Widening (Elmstead Cutting)	T. V. Holmes, F.G.S., and C. W. Osman, A.M.I.C.E.

In spite of the unseasonable weather on many of the above dates, the average attendance has been very good, and on only three occasions (May 3rd, June 21st, and July 12th) did the

number of members present fall below that requisite to obtain reduced railway fares. The loss to the Association through the taking of cheap tickets irrespective of the number of the party on the above three occasions amounted to the inconsiderable sum of 10s. 1½d. Detailed reports of the excursions in 1902 will be found in Parts 7, 8, 9, and 10 of Vol. xvii. of the PROCEEDINGS.

Thanks are due to the Directors of the Excursions, and also to the following for assistance and hospitality: Mr. Walter Collins and Miss Talbot, in Glamorganshire; Mrs. Perry Herrick, Mr. R. F. Martin, Lieut. Coke, Mr. H. Roechling, the Managers Newhurst and Whitwick Granite Co., the Secretary Leicester Waterworks, Messrs. Hodson, Messrs. Ellis and Everard, the Countess of Stamford, Mrs. Heygate, and Messrs. W. T. Tucker, Edwin de Lisle, and H. A. Payne, in Leicestershire; Messrs. F. Mitchell and — Mitchell, at Guildford; the Managers of the Waterloo and Norcot Brick-kilns, and Mr. E. J. S. Jesse, at Reading; Mrs. Kay, Fedley House, Burford Bridge; Sir Cuthbert Quilter at Bawdsey; Mr. A. H. E. Wood, at Sudbourne Park; and Mr. Ford, for hospitality at Trimingham, Norfolk.

Thanks are also due to the Secretary of the Board of Education for the following sheets of the Geological Survey Map of England and Wales:—Sheets 37, 66 S.W., 66 S.E., 67 N., 67 S., 68 E., 123 Solid, 123 Drift, and 314.

The management and arrangement of the excursions of the Association during the past year have been in the hands of the following Committee:—Messrs. Coomáraswámy, H. Bassett, E. P. Ridley, Dr. E. W. Skeats, A. E. Salter, W. P. D. Stebbing, A. C. Young, with Miss Foley as Secretary for Excursions. Messrs. Coomáraswámy and A. C. Young having signified their wish to resign, the Council on December 5th, 1902, elected Messrs. H. Kidner and G. W. Young as new members of the Excursion Committee, which therefore was constituted as follows:—Messrs. H. Bassett, H. Kidner, E. P. Ridley, A. E. Salter, E. W. Skeats, W. P. D. Stebbing, G. W. Young, and Miss Foley (Secretary for Excursions). It is recommended that the appointment of this Committee be confirmed as soon as the new Council meets.

Thanks are due to the Council of University College for the facilities they continue to offer the Association in the use of rooms for their meetings.

The changes in the House List are not considerable. Mr. J. J. H. Teall now retires from the Vice-Presidency, and from the Council; Dr. C. G. Cullis retires from the Editorship; and Mr. A. K. Coomáraswámy, Dr. E. Johnson, Mr. A. S. Kennard, and Mr. Bedford McNeill retire from the Council. Thanks are due to all of these for the assistance they have rendered in conducting the business of the Association, and especially to Dr. Cullis, who has carried out the difficult task of editing the PROCEEDINGS

during the past two years, and who, in addition to his duties as Editor, has written a considerable portion of the report of the Auvergne excursion.

The names of those suggested by the Council to fill the vacant offices will be found on the ballot paper.

On the motion of Mr. W. J. Atkinson, seconded by Mr. J. Slade, the Report was adopted as the Annual Report of the Association.

The scrutineers reported that the following were duly elected as Officers and Council for the ensuing year:

PRESIDENT:
H. W. Monckton, F.L.S., F.G.S.

VICE-PRESIDENTS:

R. S. Herries, M.A., F.G.S.	W. Whitaker, B.A., F.R.S.
C. Davies Sherborn, F.G.S., F.Z.S.	A. Smith Woodward, LL.D., F.L.S., F.G.S., F.Z.S.

TREASURER:
R. Holland.

SECRETARIES:

Percy Emary, F.G.S.	Miss Mary C. Foley, B.Sc.

EDITOR:
J. Allen Howe, B.Sc., F.G.S.

LIBRARIAN:
Henry Fleck, F.G.S.

TWELVE OTHER MEMBERS OF COUNCIL:

L. L. Belinfante, M.Sc., B. ès L.	Arthur W. Rowe, M.B., M.S., M.R.C.S., F.G.S.
Rev J. F. Blake, M.A., F.G.S.	W. P. D. Stebbing, F.G.S.
C. Gilbert Cullis, D.Sc., F.G.S.	Captain A. W. Stiffe, F.G.S.
Prof. E. J. Garwood, M.A., F.G.S.	Miss E. Whitley, B.Sc.
Upfield Green, F.G.S.	A. C. Young, F.C.S.
F. L. Kitchin, M.A., Ph.D., F.G.S.	
John E. Piper, LL B.	

The best thanks of the Association were then voted to the Officers and Members of Council retiring from office, to the Auditors, and to the Scrutineers.

The President then delivered the annual address, entitled, "The Recent Geological History of the Bergen District of Norway."

On the motion of Mr. J. J. H. Teall, seconded by Mr. W. Whitaker, it was unanimously resolved that the President's address be printed in full.

This terminated the Annual Meeting.

ORDINARY MEETING.

FRIDAY, MARCH 6TH, 1903.

H. W. MONCKTON, F.L.S., F.G.S., President, in the Chair.

C. J. Coleman was elected a member of the Association.

Mr. C. D. Sherborn then read a paper by Mr. A. J. Jukes Browne, on "The Zones of the Upper Chalk in Suffolk," after which Dr. A. Smith Woodward gave an account of his recent examination of the Pliocene Bone Bed of Concud, Teruel, Spain, his remarks being illustrated by lantern slides.

GEOLOGISTS' ASSOCIATION.

FOUNDED 1858.

THE OBJECT of the Association is to facilitate the study of Geology and its allied Sciences.

THE ASSOCIATION consists of Ordinary and Honorary Members.

ORDINARY MEMBERS are elected on a Certificate of Recommendation, signed by two or more members, one of whom must have personal knowledge of the Candidate. The certificate is read at a monthly meeting, and the Candidate submitted for election at the succeeding Meeting.

Ordinary Members pay an Admission Fee of 10s.; and an Annual Subscription of 10s., or a Composition Fee for the latter of £7 10s. (£5 5s. if elected before November, 1893).

LADIES AND GENTLEMEN are eligible for election.

HONORARY MEMBERS (limited to 20), consisting of persons who are eminent in Geological Science, or who have rendered some special service to the Association, are elected, on the recommendation of the Council, at the Annual General Meeting.

THE COUNCIL, in which the management of the affairs of the Association is vested, is elected annually, and is composed of a President, four Vice-Presidents, a Treasurer, one or more Secretaries, an Editor, a Librarian, and twelve other Members.

MEETINGS are held at University College, Gower Street, W.C., on the first Friday in each month from November to July inclusive. Two visitors may be introduced by each Member. The chair is taken at 8 p.m. (7.30 p.m. at the Annual Meeting).

FIELD EXCURSIONS and Visits to Museums and other places of Geological interest are made at various dates, principally between March and August.

THE LIBRARY of the Association is deposited at University College, Gower Street, W.C., and is accessible to Members from 9 a.m. to 8 p.m. during College Term, and from 10 a.m. to 5 p.m. during Vacation. Members are entitled to borrow one volume at a time, which may be retained one month. Members residing in the country may, on application to the Librarian, have books sent to them on their paying cost of carriage both ways. Members of the Association are permitted to consult all books in the Science Library of University College. They are also permitted to borrow books from this Library, subject to the approval of the College Librarian.

THE PROCEEDINGS AND MONTHLY CIRCULARS are forwarded post free to all Members whose addresses are known, and who are not in arrear with their subscriptions.

Forms of proposal for Membership, and any further information, may be obtained by application to the Secretary,

PERCY EMARY, F.G.S.,

12, *Alwyne Square,*

Canonbury, London, N.

Vol. XVIII. 1903. Part

PROCEEDINGS

OF THE

Geologists' Association.

EDITED BY

J. ALLEN HOWE, B.Sc., F.G.S.

(Authors alone are responsible for the statements in their respective Papers.)

Contents.

* *Advance Copies of this Paper were issued in July, to Members taking part in the Long Excursion.*

LONDON:

UNIVERSITY COLLEGE.

EDWARD STANFORD, 26 & 27, COCKSPUR STREET, CHARING CROSS, S.W.

Issued Oct. 5th, 1903.] C [PRICE 1s. 6d.

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GEOLOGISTS' ASSOCIATION, LONDON.

OFFICERS AND COUNCIL,

Elected February 6th, 1903.

PUBLICATIONS OF THE ASSOCIATION

Uniform with PROCEEDINGS, *pp. viii*, 129, *with Index of Genera and General Index.* 13 *Sections in the text and a folding Map.* *Price* 3/- (2/6 *to Members*). *Postage*, 3*d.*

"On the Eocene and Oligocene Beds of the Paris Basin."

By Geo. F. Harris, F.G.S., and H. W. Burrows, A.R.I.B.A.

This Paper comprises:—(1.) A detailed **Description of the Beds**, the result of several years' careful study of the Parisian Tertiaries and close communication with many eminent French geologists. (2.) A practical **Guide for the Field-Geologist** to all the best exposures, based on personal experience. (3.) A Revised **List of the Mollusca**, showing their range in time, with Lists of other **Fossils**.

(*Continued on page 3 of the Cover.*)

THE GEOLOGICAL HISTORY OF LOWER TWEEDSIDE.

By JOHN GEORGE GOODCHILD (of the Geological Survey, F.G.S., F.Z.S., Custodian of the Collections of Scottish Geology and Mineralogy in the Edinburgh Museum of Science and Art).

(*Read June 5th*, 1903, *a few advance copies issued to Members in July* 1903.)

MOST persons would probably find it a somewhat difficult matter to obtain a good general idea of the geological features found in such a district as Lower Tweedside if the facts were presented in the manner usually adopted. It may be better, therefore, to state the essential features that have been brought to light as a result of careful surveys of the district, mostly in the narrative form first, and then to give a summary in the usual manner. The readers will probably find that this plan will enable them to obtain a better view of the facts and to comprehend the essential features much more easily than would otherwise be possible.

A summary of the chief points in the stratigraphy following this historical introduction ought, with the aid of good geological maps and the accompanying sections, to make the geological history of Lower Tweedside sufficiently clear for the purpose required.

The district here specially referred to comprehends part of the Southern Uplands on the one side of the Tweed, together with the north-eastern part of the Cheviot Hills on the other; and with the broad lowland area, known as the Merse, between these two. Roughly stated, it may be described as forming the lower half of the basin of the Tweed. On the east it may be regarded as limited by the coast line northward of Berwick as far as the Siccar Point, and southward of Berwick as far as Scremerston.

Within the area thus roughly defined occurs a considerable variety of geological formations, as may be seen by reference to the following table, in which those mentioned are stated in descending order.

C.—Neozoic Rocks.

NEWER:

3. Pleistocene.
2. Some basalt dykes of Tertiary age, and possibly the contents of some of the mineral veins.

OLDER:

1. The Magnesian Limestone, as well as vestiges of the former presence of other New Red Rocks.

Unconformity.

B.—Deuterozoic Rocks.

NEWER:

5. The Whin Sill.
4. Upper Carboniferous.
3. Lower Carboniferous.
2. Upper Old Red Sandstone.

Unconformity.

OLDER:

1. Caledonian Old Red.

Unconformity.

A.—Proterozoic Rocks.

Silurian.

8. Lanarkian Rocks.
7. Downtonian = Ludlow in part.
6. Salopian = Wenlock in part.
5. Valentian = Llandovery.

Usually an unconformity here.

Ordovician.

NEWER:

4. Bala Rocks.
3. { Upper. / Lower. }

OLDER:

2 Llandeilo.
1. Arenig.

With these occur granites, together with various dykes, which mostly consist of porphyrite. Both of these are of Devonian age; there is also the Post-Carboniferous Whin Sill; and a few dykes which may be of Tertiary age.

HISTORICAL GEOLOGY.

The Ordovician Rocks occur within the basin of the Tweed, chiefly along its north-western margin. They will not be visited by the Geologists' Association on this Excursion. But, seeing that they underlie the district which will be examined, their general characters may be briefly referred to here. The lowest rocks seen consist of eruptive rocks of sub-basic composition, chiefly andesitic lavas. These are succeeded by a widespread,

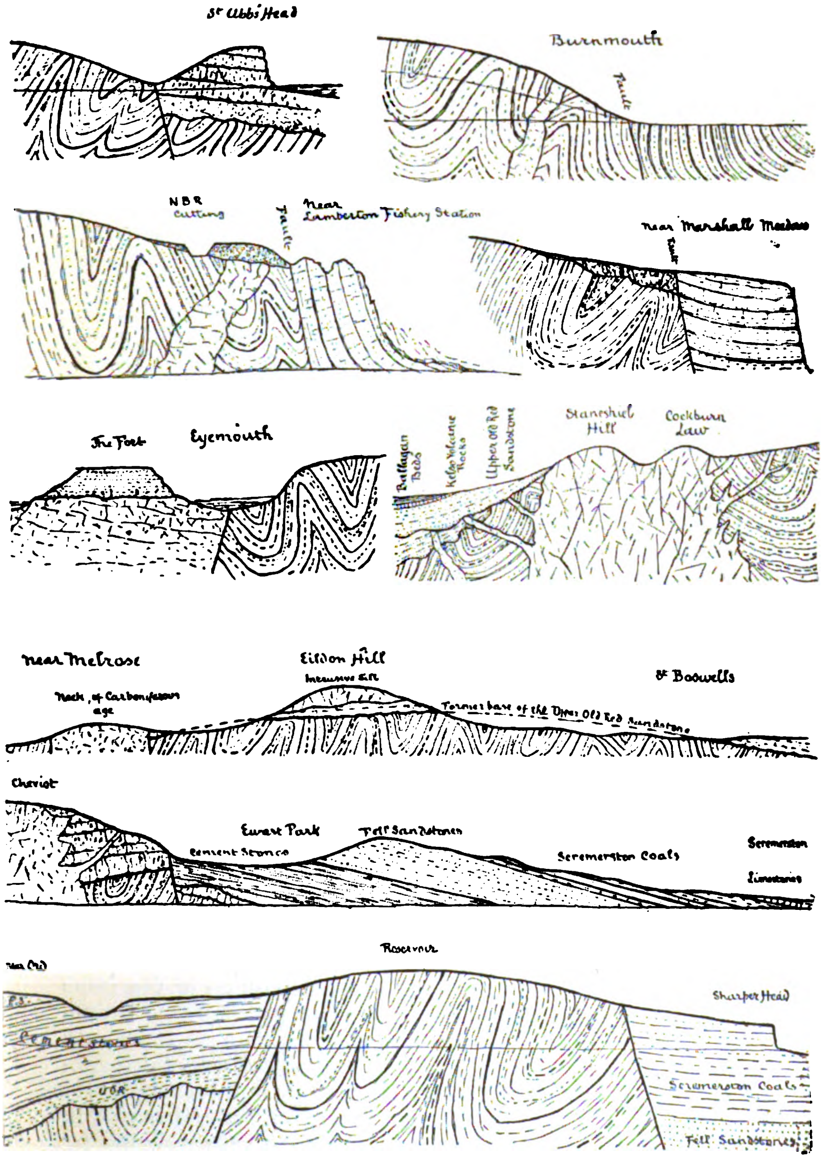

FIG. 1.—DIAGRAMMATIC SECTIONS ILLUSTRATING THE GEOLOGICAL STRUCTURE OF CERTAIN PARTS OF LOWER TWEEDSIDE.

but nowhere very thick, deposit of chert, which was first recognised by the officers of the Geological Survey as consisting of radiolaria, which were afterwards figured and described by Dr. Geo. Hinde. The deposit agrees in all essential respects with the modern deep-sea radiolarian oozes, and it is generally regarded as having been formed under the same conditions of depth as the recent ooze referred to. The Arenig Radiolarian Chert is followed, in places, by black shales, of small thickness, which contain the graptolites characteristic of the Skiddaw Slates, and are, therefore, of Arenig age. The Radiolarian Cherts, and the lava just referred to, are, therefore, much older than the Ordovician volcanic rocks of the Lake District.

Rocks of Upper Ordovician age succeed these, and, especially in the areas to the south-west of the basin of the Tweed, they show the evidences of unconformity to the rocks below which are seen in many other areas on this geological horizon. Within the district especially under notice there is, however, no stratigraphical break between the Upper Ordovician rocks and the strata of older date, although the palæontological break is very marked. They consist mainly of black shales and mudstones similar in character to those below and above.

Further information upon these rocks should be obtained from the Memoir of the Geological Survey dealing with the "Silurian Rocks" of Scotland.

The succeeding Silurian Rocks, which in so many areas lie with a more or less well-marked unconformity upon the beds below, here repose, without any evident stratigraphical discordance, upon the rocks last referred to. Their lowest member is usually a thin band of black shale, within which rocks of a more arenaceous type are locally intercalated. Although there is no evidence of any stratigraphical break, the palæontological evidence clearly points to the existence of a considerable biological break, just as is found to be usually the case elsewhere upon this horizon in Britain. It is evident that tolerable uniformity of depth, and of geographical conditions in general, prevailed throughout the whole period when these black shales were in process of formation. Hence the same type of deposit continued from Llandeilo times until long after the advent of the first rocks of Silurian age. It seems possible that the curious fact of the continuous deposition of the same lithological type of rock material, while the palæontological conditions changed in so marked a manner from time to time, may be explained on the assumption that the Graptolites (which constitute the greater part of the fossils occurring in these rocks) may have passed through a free-swimming stage in the earlier part of their existence, in much the same way as is the case with the fry of the Cœlentera in general, and that periods of the cold condition of the ocean surface waters alternating with warm may have led to the extermination of certain species, and have thus favoured the

evolution of new species of allied forms. In dealing with this difficult problem, in a paper recently published by the Royal Physical Society, I have ventured to speculate whether these alternations may not have been connected with the recurrent cycles of changes brought about by Precessional causes.*

As the Association on this occasion will not visit the localities where these lowest Silurian Rocks rise to the surface, we may pass on to the consideration of the strata which succeed, and which will form a conspicuous object in the landscape to be seen on at least two of the excursions. The rocks referred to are the Gala Rocks, whose fossils indicate, in a manner that is unmistakable, that they are of Tarannon age. These Gala Rocks form the higher group of the Valentian sub-division of the Silurian System.

The Gala Rocks appear to be mainly the chronological equivalents of the Pale Slates of the Lake District, formed, apparently, in sea-water of lesser depth than these, and consisting almost entirely of terrigenous materials. Petrographically the Gala Rocks bear a very close resemblance to the Coniston Grits of the Lake District, from which, however, their fossils clearly show that they are quite different in age. With some unimportant exceptions the fossils of the Gala Rocks consist of Graptolites. The following list comprehends all the species which have yet been recorded from these rocks:—*Diplograptus sinuatus; Cyrtograptus grayæ, Monograptus galaensis, M. hisingeri, M. spiralis, M. concinnus, M. exiguus, M. colonus, M. priodon, M. pandus, M. convolutus, M. crispus, M. turriculatus, M. leptotheca, M. sedgwickii; Rastrites peregrinus, Retiolites geinitzianus, Dictyonema delicatulum.* The other fossils just referred to are chiefly tracks and traces, which cannot with certainty be referred to their true position in the organic world.

Unlike the Pale Slates, the Gala Rocks are of considerable thickness; for instead of being only some six hundred feet, these latter may well have a thickness of even as much as two thousand feet. But owing to the excessive plication these rocks have undergone, and also to their general uniformity of petrographical characters, no trustworthy estimate of their thickness can be made.

The Gala Rocks are described in the Geological Survey Memoir, *op. cit.*, p. 201, as consisting, in the lower parts, "of massive grits and greywackes (Queensberry Grits) which locally merge into conglomerates," and in their higher parts "which pass conformably upwards into the Wenlock formation," of "brown-crusted flags, with grey, green, or red shales, and bands of brown or yellow greywacke from one to two feet thick (Hawick Rocks)." And on p. 209 of the same memoir, it is stated that the Queensberry Grits form the coast line between Cockburnspath and St.

* "The Cœlentera in Relation to Geological Zones." *Proc. Roy. Phys. Soc.*, vol. xv. p. 47, 1902, and *Trans. Geol. Soc.*, Glasgow, vol. xii, p. 35.

Abb's Head, while the peculiar lithological type representing the Hawick Rocks is found near Eyemouth.*

The Gala Rocks are succeeded by rocks of Wenlock age, and these, in their turn, by undoubted Ludlow Rocks, which are well seen in the Pentland area. The small thickness assigned to the Wenlock Rocks in the South of Scotland is somewhat startling to anyone who is familiar with the grand development they present in the Lake District. It will be observed that the vast group of strata, fully eight thousand feet in thickness, which form the Coniston Flags and Grits (Wenlock) in the area just mentioned, is considered by the authors of the memoir to be either absent entirely, or to be reduced to dimensions so insignificant as to be unworthy of special mention.

Leaving this (to me) vexed question, I may briefly refer to the next higher members of the Silurian Rocks, which form a belt on the south-east of a line passing through Dumfries and Jedburgh, and which, if exposed at the surface, would run along the south side of the Tweed to Berwick. To anyone familiar with the Lake District Silurian Rocks these appear to resemble the Bannisdale Slates. Small areas of rocks which are on this horizon will be seen in the course of the excursions. Strata contemporaneous with the Pentland Ludlow Rocks do not occur anywhere near the area under notice. Nor do the still-higher groups of beds to which, in the Survey Memoir, the name "Downtonian" is applied.†

The Lake District Silurian Rocks are somewhat above thirteen thousand feet in thickness, the Lanarkian rocks there being absent. For purposes of comparison with the Scottish type, it may be well to give their succession and thickness here:—

		Feet.
f.	Kirkby Moor Flags	+2,000
e.	Bannisdale Slates	5,200
d.	Coniston Grits	4,200
c.	Coniston Flags	2,000
b.	Pale Slates	10 to 450
a.	Graptolitic Mudstone . . .	0 to 30

Of these *b* is represented by the Rocks between Cockburnspath and St. Abb's Head; *c* and *d* may, possibly, be the equivalents of the Hawick Rocks; and *e* may be the equivalents of the rocks between Hawick and Riccarton. The Kirkby Moor Flags seem to be represented in the Pentland area by the strata between the Lanarkian Rocks and the Eurypterid Beds in the Gutterford Burn

* I do not intend to discuss here the relations of the higher of these rocks to the Silurian strata of the Lake District; but I have not yet seen my way to adopting the view that the Hawick Rocks are of Tarannon age. The late Mr. Aveline and I, twenty-five years ago, officially expressed the opinion that they were of the same age as the Coniston Flags and Grits.—J. G.G.

† These latter used to be regarded as Lower Old Red, and they are the same as those for which some years ago I suggested the name Lanarkian.

there. Regarding the correlation of the rest, further evidence seems to be required.

On any view of the thickness of the Silurian Rocks of the South of Scotland the total, from the Birkhill Shales to the highest beds seen, must amount to many thousands of feet. The whole of the rocks, from base to summit, appear to have been formed during a prolonged period of terrestrial movements, during which the local phase of the undulation to which the deposition was due mainly took a downward direction.

It does not appear to be accurately known what amount of downward movement of a terrestrial undulation is possible, but it seems probable that it rarely exceeds some fifteen thousand feet. It appears reasonable to assume that all such downward phases of terrestrial undulations are accompanied by their correlative upward phases of movement, and that, in course of time, their onward travel carries the downward phase to an area adjacent, and that its former place is taken by a contemporaneous movement in the opposite direction. The distance between the areas where these respective phases occur may be spoken of as the "wave-length" of the undulation in question. Using still the language of the physicist, we may refer to the "amplitude" of the undulation, and also to its "period," as useful terms expressive respectively of (1) the ratio between the extent of the area affected by either phase and the vertical extent of the movement, and (2) the time occupied in bringing about a given amount of vertical movement. Using these terms, we may state that the undulatory movements to which the deposition of the Silurian Rocks were due, were characterised by great wave-length and amplitude, and by low frequency. In other words, the time occupied by the downward phase coincided with the whole of the period from the commencement of the Birkhill Rocks to near the close of the time when the Lanarkian Rocks were laid down; and that the area affected by these conditions was one of very great extent.

Following the last downward phase of movement came one of movement in the opposite direction. The septum (or datum line between the upward phase and the downward) slowly travelled in a direction transverse to the front of the wave, so that conditions favourable for upheaval followed in the rear of those which had previously given rise to depression. The upward phase of movement appears to have been characterised by greater amplitude, lesser wave-length, and higher frequency, than that phase which preceded it.

Putting this statement into a different form, we may say that before the downward movement had quite ceased in the area now represented by the South of Scotland, upheaval had commenced in an area adjacent, and that, by degrees, the area specially under

consideration also became the theatre of movements of a similar kind. It was under these circumstances that the Lanarkian, or so-called "Lower Old Red," was formed, Then, as the upward phase began to take a more decided character, sedimentation came to an end and denudation commenced. Perhaps the following diagram may serve to make this somewhat complex relationship clearer. It is intended to show that one effect of prolonged compression is to throw the strata nearer the centre of the fold into complex plications, while the surface formed by the mass undergoing compression became the principal area of

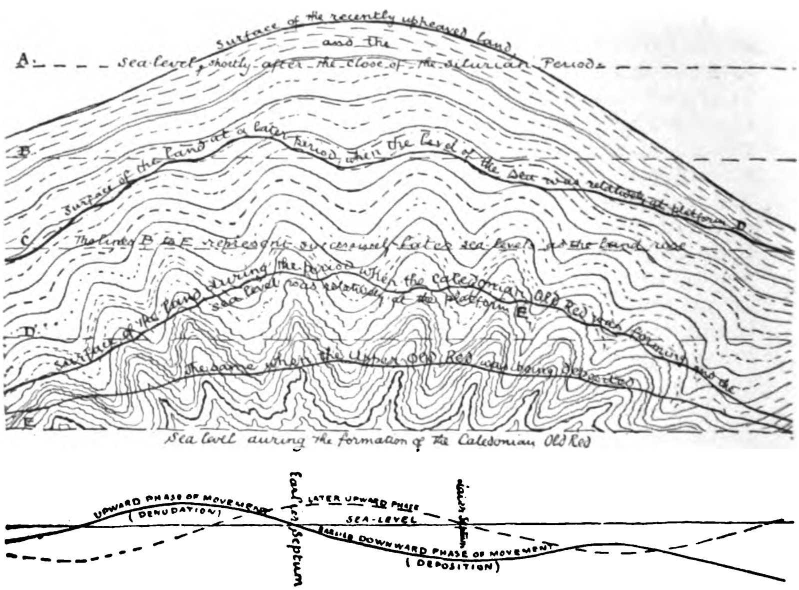

FIG. 2.—DIAGRAM TO ILLUSTRATE THE EFFECTS ARISING FROM TERRESTRIAL MOVEMENTS AND DENUDATION IN NORTH BRITAIN DURING THE DEVONIAN PERIOD.

elevation. Denudation, not at first keeping pace with the upheaval, shaped mountain masses out of the part undergoing uplift, and, eventually, when the elevatory forces were acting with less effect, the central, highly-crumpled inner portions of the folds were brought to the surface, and planed down by subaërial waste into a more or less irregular base-level of denudation.

That the part now forming the Southern Uplands of Scotland is the area where the Silurian Rocks exhibit these flexures in the highest degree of complication seems to indicate that it was over this area that the chief centres of elevation of the Silurian *massif* lay. And as it is precisely along such lines of intense crumpling

that dynamic action produces the maximum of crushing, so it is there also that one might reasonably expect that the greatest evolution of heat took place, as a result of the conversion of the energy of motion into heat energy. The view that volcanic action is due primarily to this cause, and secondarily to the influx of sea-water to zones of high temperature within the Earth's crust, seems now to be coming more and more into general favour. I shall here assume that it offers a satisfactory explanation of most of the chief phenomena connected with volcanic action, and shall go on to connect the volcanic phase which succeeded the Silurian period with the events just described.

There is not yet quite sufficient evidence to enable us to form any decided opinion regarding the direction of main upheaval at the close of the Silurian period; but as the axes of the folds run in a general east-north-easterly direction, and as, furthermore, strata of marine origin (the true Devonian Rocks) were formed at this period in the area to the south and the south-east of the area specially under consideration, we may reasonably conclude that the main axis of upheaval (and presumably, therefore, of the mountain area) ranged in an east-north-easterly direction through Britain into what is now Scandinavia, and that, south-eastward from that, the slopes gradually became less and less steep, and the crumpling of the underlying rocks still less strongly marked, until the Silurian Rocks gradually passed without a break (and with but little contortion in their inner parts) into the marine Devonian Rocks.

The foregoing explanation is somewhat complicated : but then, on the other hand, so are the facts that have to be accounted for. In Scotland occurs a highly-convoluted and greatly-denuded set of Silurian Rocks, which are followed unconformably by a set of volcanic rocks of Devonian age. In an area not far to the south the Silurian Rocks are neither crumpled nor denuded to any great extent, and are succeeded, apparently quite conformably, by the marine strata of Devonian age. It must be remembered that the volcanic rocks which form the Cheviot and Pentland Hills belong to a period of the Earth's history which is represented in England only by some part of the Devonian Rocks of Devonshire, and the reason why a marine type occurs in the one area, and a continental type is found in the other, is important to be borne in mind.

What appears to have happened is, that lagoon conditions followed those of a purely-marine character under which the Ludlow Rocks were formed; and it was under alternate lagoon and open-sea conditions that the Lanarkian Rocks were formed. Then, as the septum travelled forward, upheaval began, continental conditions set in over the area where there had previously been marine; and, finally, upheaval gaining ground over denudation, mountain masses were formed. These supplied the materials out

of which the Caledonian Old Red Conglomerates were made. Eventually volcanoes broke out along the line of chief dynamic effects, and the period when the rocks now forming the Cheviot Hills first came into existence was ushered in.

There is no need to enter into much detail in regard to the Caledonian Old Red Volcanoes, beyond stating the fact that there appear to have been many centres whence the eruptive masses reached the surface. Even though it may not be quite in accordance with the facts to state that each granite mass of the south of Scotland and of the north of England represent the core of one of these volcanoes, there is no reasonable doubt that these great eruptive masses were connected in origin with the volcanoes in question. The four granite masses of the Lake District may be of different ages, but there cannot be much doubt that the granite of Shap, perhaps that of Wastdale also, and possibly the granite of Skiddaw, may all be of the age under consideration. The same is true of the great granite masses of Galloway. Cockburn Law, which will be visited by the Association, is of the same age. So, farther north, are such masses as the granites of Loch Awe and Cruachan, and even some of the newer granites of other parts of Scotland. The evidence in regard to the age of most of the more southern masses is sufficiently clear; for the granites pierce the contorted, and even the cleaved, rocks of Silurian age, and are therefore of later date than the disturbances to which these are due; and fragments of these granites, or of their apophyses, occur as constituents of the Upper Old Red Sandstone. Further reference will be made to this latter point in another connection.

The essential features to be borne in mind in studying the relationship of the Caledonian Old Red Volcanic Rocks to the rocks of Silurian age are that the volcanic rocks lie with a violent unconformity upon the Silurian (and Ordovician) Rocks, and that the amount of disturbance the volcanic rocks have undergone is, in general, so trifling that the fact is perfectly evident that the chief disturbances are of older date than the volcanic rocks. It follows also that the chief denudation took place prior to the deposition of these latter. The great unconformity between the Carboniferous Rocks and those of older date (which represents the removal of a thickness of quite five miles of rock in the Lake District) took place in the interval between the close of the period when the Ludlow and Lanarkian rocks were formed, and the outbreak of volcanic action. Geologists seem a little apt to overlook the important bearing of this fact upon many questions of interest, and especially in connection with such matters as those relating to geological time.

It is a somewhat remarkable fact that the prevailing lithological types of the eruptive rocks, and especially of the lavas, associated with the Caledonian Old Red Sandstone in the Lorne area, the Ochils and the Sidlaws, the Pentland Hills and the Cheviot area,

are sub-basic. Andesites everywhere predominate, though andesitic-basalts and even basalts are not unknown, and trachytes occur here and there, especially amongst the lavas of later date. The other noticeable features are the feeble development of pyroclastic rocks and the paucity of dykes. Fully nine-tenths of the mass in each area consists of lavas, with only an occasional, and rarely very thick, band of tuff between. Furthermore, interstratifications of material of sedimentary origin appear to be nearly everywhere confined to what there is reason to believe were the outskirts of the particular volcano whose relations happen to be under consideration. Evidently these volcanoes were characterised by quiet effusive eruptions, and it is further evident, from the nature of the few rocks of sedimentary origin associated with the lavas, that the volcanoes were mainly subaërial, and were found under continental conditions.

Some reference was made to the dykes a few lines above this. It is, perhaps, exactly what might have been expected, that those which do occur are either sub-acid or sub-basic in composition. The dominant type is that lithological variety to which the name PORPHYRITE is now very properly restricted. These are holocrystalline aggregates consisting largely of a finer-grained base of plagioclase felspars, together with Hornblende and Biotite, and often with larger idiomorphic crystals of felspar, which, in most cases, are of a plagioclase variety also—perhaps Oligoclase, in the majority of cases. These porphyrites are of some importance in the geology of the district under consideration, inasmuch as they constitute by far the commonest dyke-rocks which traverse the Silurian strata; and, furthermore, because their marked lithological character renders their identification amongst the constituents of some of the conglomerates, such as those of the Upper Old Red Sandstone, a task of very small difficulty.

There seems reason to believe that most of these porphyrites are really late off-shoots from areas of granite, as those of their age in Scotland are all more or less plagioclase-granites, in which Muscovite is rare or absent, except in the pegmatites, and in which the dominant ferro-magnesian constituents are Biotite and Hornblende.

There are two granite areas within a short distance of Berwick. One of these is that of Cockburn Law, which rises through the Silurian rocks near Duns; and the other is that which forms the core of the Cheviot Hills not far to the south-west of Wooler.

The Cheviot granite is clearly intrusive in the andesite lavas, which exhibit some interesting modifications where the two rocks come into contact. These have been described by Clough, Kynaston, and others. It appears to me to be at least possible that the granite may, in part at least, represent andesite lavas which have been melted up by the action of thermal waters

charged with alkalies. The dissolved salts found in inland lakes or in the sea must become concentrated by prolonged "boiling" in every case where the water finds its way down to the focus of volcanic action; and solutions thus formed are quite competent both to dissolve eruptive rocks and to add to the solutions thus formed an increased percentage of alkaline matters. When the temperature of the compound declines, and the aqueous solvent escapes, crystallisation of the residue gradually ensues, and granitoid rocks are the result.

The andesitic lavas of the Caledonian Old Red Sandstone are quite commonly vesicular, especially on their upper sides. These vesicles are often found to be the repository of agates. Agates of the normal type occur in the andesite lavas of St. Abb's Head, while those occurring in the Cheviot area are often more or less of the nature of the carnelian agate, or even of jasper agates. An interesting feature about these is connected with the fact that these agates (as well as the fragments of the porphyrite dykes already mentioned) occur as constituents of the Upper Old Red conglomerates. Hence it is evident that the growth of the agates had been completed before the advent of the Upper Old Red Sandstone.

No fossils of any kind have yet been found in rocks of the age under consideration, at least, within any area nearer than the Ochils.

There is no clear evidence to show what the nature of the climate was at the time the Caledonian Old Red Rocks were in process of formation. The conditions were continental and not marine, and there must have been lofty uplands from which the materials were derived which form the basement (and other) conglomerates of this series. No arkoses have yet been found in these rocks, whence perhaps it is safer to assume that the climate was not as arid as it clearly became later on.

If the view is correct that the rocks of St. Abb's Head, Eyemouth, and the Cheviot Hills are of the same age as those of the Pentland Hills and the Ochils, it would seem to follow that these represent the earlier-formed part of a great series of rocks whose higher members are the Orcadian Old Red (the true Middle Old Red) of the Moray Firth, Caithness, Orkney, and Shetland. Dr. Traquair has conclusively shown that the two divisions referred to are quite separate in age, and that both are older than the true Upper Old Red Sandstone. This latter formation lies uncomformably upon every rock older than itself, and hence must be separated from the older series by a vast interval of time. It is, however, not a little remarkable that, although the field evidence relating to this unconformity is perfectly clear almost everywhere, the actual junction between the Upper Old Red and

the Caledonian Old Red is seen only in a very few places. One of these, and this not a good one, is at Eyemouth, and will probably be examined by the Association.

The Upper Old Red Sandstone has been examined on the occasion of the visit of the Association to Edinburgh, but there will be several opportunities of seeing it again under various other conditions. The striking unconformity between the Upper Old Red Sandstone and the Silurian Rocks, which is so clearly shown at the Siccar Point, may be examined under circumstances almost equally favourable close to Cockburn Law. In this connection it may be well to repeat the statement that the Upper Old Red, on the outskirts of the Lake District, oversteps older rocks whose aggregate thickness exceeds five miles. There is no reason to think that the hiatus on the northern side of the Border is of lesser extent than that; indeed, if we take into account the aggregate thickness of the Orcadian Old Red, the Caledonian Old Red, the Silurian, Ordovician, and Cambrian rocks there, it must be nearly seven miles.

The history of the Upper Old Red may be regarded as a continuation of that under which the older members of the series were formed. The coarse nature of many of the conglomerates points clearly to powerful torrential action, and therefore to the presence of high ground at no great distance. The constituents of the conglomerates include, of course, a large percentage of the greywackes which form the greater part of the Silurian Rocks; but fragments of granite are also found, and with these occur, much more commonly, representatives of the porphyrite dykes already mentioned. A few rocks which cannot be discovered anywhere near *in situ* may also be found. Some of these may have been derived from the conglomerates of the Caledonian Old Red, others from conglomerates older still, such as those which occur in connection with the Upper Ordovician Rocks of the West of Scotland. The blocks of limestone which are so commonly found in the Upper Old Red of the North of England, are rare here, or absent entirely.

The sandstones and marls of the Upper Old Red as developed in the basin of the Tweed, are deeply imbued with ferric oxide. Mr. Hudleston's explanation of the origin of this red colouration (*Proc. Geol. Assoc.*, vol. xi, No. 3, p. 104) satisfactorily accounts for this characteristic feature. A certain proportion of the sand grains clearly represent desert sands, being, indeed, quite as well-rounded as the sand grains from the Sahara or other modern regions where desert conditions obtain.* The sand grains of much of the Upper Old Red are enlarged by the addition of secondary quartz.

* See Goodchild, "Desert Conditions in Britain," *Trans. Geol. Soc. Edin.*, vol. vii, p. 203.

This feature is well seen at several localities within the basin of the Tweed.

The normal Upper Old Red Sandstone is usually devoid of calcareous matter in any but its uppermost part; but in the sandstones, and also in the marls, of this portion, concretionary nodules and angular flakes of calcareous matter are of frequent occurrence in almost every locality. This is so marked a feature that the upper sub-division is now usually distinguished as the Cornstone Group. The distinction between the upper and the lower sub-divisions may well be stated here. The lower sub-division consists of an extremely variable series of conglomerates and sandstones, the former being of more common occurrence near the base, and the sandstones becoming finer-grained, more inter-stratified with marls,* and more largely composed of desert-sand grains. Its prevalent colour is never that of any of the greys which characterise rocks found under normal sedimentary conditions, nor is it any shade of purple, but it is usually more or less bright red, owing to the sand grains being coated with films of ferric oxide; and with the red occur cream-coloured patches and bands of such green colour as might be due to the presence of ferrous silicate. The thickness, as might be expected to be the case, is subject to considerable, and, usually, more or less abrupt, variation. It may be as much as two hundred and fifty feet at several parts of the Tweed valley. Where fossils occur in it they are usually very fragmentary, and they have hitherto been rarely those of any other organisms than the Ostracoderm *Bothriolepis obesa*, which Dr. Traquair has identified from several localities within the area under consideration; or else scales of the Crossopterygian fish *Holoptychius nobilissimus*. Fragments of *Palæopteris hibernica* occur near Duns.

The upper or Cornstone sub-division is usually of a much less pronounced red colour, it rarely contains desert-sand grains, and it is characterised nearly everywhere by the presence of irregular lumps, flakes, and concretionary masses of calcareous matter. Suncracks occur on all platforms, and rain printed surfaces of the clays are far from being uncommon. Where these rocks have been formerly covered within a small vertical distance by the Trias the calcareous matter shows a tendency to pass into hæmatite. This is well seen at several places on the Berwickshire coast. A few obscure traces of plants have been found in the Cornstone Group, though but little else has yet occurred.

As the presence of concretionary carbonate of lime is characteristic of the succeeding members of the Lower Carboniferous Rocks, as well as of the higher portion of the Upper Old Red Sandstone, over wide areas, it will immediately occur to any geo-

* The word marl does *not* necessarily mean a clay containing calcareous matter. In the North of England the name is applied to *any* rock that readily "merls" or crumbles to pieces on exposure to the air.

logist to inquire what may be the cause of its general distribution on this particular geological horizon. Many explanations may be offered; but a consideration of the following may help to cast some light upon this somewhat obscure subject:

The presence of grains of desert-sand on many platforms in the Upper Old Red Sandstone, the prevalent bright-red colour of the rock, the strong false-bedding, suggestive of desert-sand dunes, the angular character of much of the material forming the conglomerates, and their large size and tumultuous mode of accumulation, the constant occurrence of casts of desiccation cracks and the frequency of rain-pitted surfaces, all combine with the irregular mode of occurrence of the rock to indicate that it was formed under continental conditions, and during the prevalence of an arid climate. With a rainfall unsuited for the growth of vegetation, and with a land surface largely characterised by surfaces consisting of bare rock, screes, wadies filled with torrential deposits hurried into them after the occasional heavy rainfalls, with an ever-drifting cover of desert-sand, and with no areas of water except such as gave rise to shallow pools, charged with concentrated solutions of sulphate of lime, etc.—no vegetation, but such as was specially suited for desert condition, could be expected to live. With little or no vegetable matter available for food, animal life certainly could not flourish; and it is probable that even the few organisms whose remains do occur in these rocks may have been swept into the desert areas by spates originating in adjacent areas where the conditions for the maintenance of animal life were of a more suitable nature. Mr. Hudleston (Presidential Address, *Proc. Geol. Assoc.*, vol. xi, No. 3) has dealt with the effect of these conditions in relation to the ferruginous colouring matter of rocks, and the reader would do well to refer to that article for further information. I also, some years afterwards, took up the subject in the opening address to the *Edin. Geol. Soc.*, vol. vii, pp. 203-222, on November 19th, 1896, under the title of "Desert Conditions in Britain," to which the reader may care also to turn.

It may be safely assumed that the Upper Old Red Sandstone was formed at a period when the land stood well above the sea level. But when the downward phase of the terrestrial undulation to which this elevation was due had begun its advance towards the region under consideration, the arid climatal conditions that accompanied the upward phase of movement gave rise to conditions under which the rainfall, if not more copious, was at least more regular, in its occurrence. Under these more genial conditions vegetation again sprang into existence here, and with the advent of more suitable conditions animal life, too, began to flourish.

So it came about that, under transitional conditions, organic matter was much more frequently transported by the streams into the saline lakes. Not only did the iron in solution, under these

changed conditions, tend to pass into the usual hydrated condition, so that the sand grain less frequently became coated with films of the red sesquioxide, but another change ensued, which is the one that we are chiefly concerned with here. Assuming that the lakes and schatts into which the rivers discharged were still areas where the water carried into them was dissipated by evaporation, it would follow that the dissolved constituents of the river-water eventually became more or less concentrated. Amongst the substances thus accumulated may safely be counted solutions of sulphate of lime. These, when brought into contact with decomposing organic matter, underwent certain chemical changes, one of which resulted in the precipitation of the lime in the form of the carbonate. Thus, it seems probable, thin sheets of chemically-formed carbonate of lime were formed in the shallows—evaporation, of course, also taking a part in the process; and, then also, as it appears to me, nodular masses of calcareous matter were formed in the sediments that were in process of deposition. Putting this statement into another form, one may say that the presence of these nodular masses and flakes of carbonate of lime are an index to the return of a humid climate after a period of arid and continental geographical conditions. The Cornstones, therefore, on this view, present us with an important link in the chain of evidence bearing upon the transitional nature of the climate that characterised the close of Old Red times and the commencement of the Lower Carboniferous Period.

Then, as the rocks which succeed the Cornstones (the Ballagan Beds or Lower Limestone Shale) represent a set of accumulations formed when the downward phase of terrestrial movement had begun to make its influence still more strongly felt, we find that calcareous concretions of much the same character continued to be formed whenever the suitable conditions obtained. The reader who happens to be familiar with the terrene formed by the Keuper Marls, the Rhætic Beds and the Lower Lias, may advantageously make a mental comparison between these two sets of formation. The Keuper Marls form a parallel to the Upper Old Red, the Rhætic Beds (in Britain at all events) to the Ballagan Beds, and the Lias to the purely-marine phase of development of the Lower Carboniferous Rocks.

It may be added here that the flakes of carbonate of lime, which have been several times alluded to in the foregoing paragraphs, represent sheets of chemically-precipitated matter deposited in the shallows of the old lakes, and broken up, as shore-ice is apt to be, when the level of the water rises, and thence floated away into deeper water, eventually to subside upon the bottom, and become an integral part of the sediments there accumulating.*

THE LOWER CARBONIFEROUS ROCKS.—It may be stated here that there existed until the last few years some misconception with

* See *Proc. Geol. Assoc.*, xv, 4, p. 127 (1897).

regard to the correlation of the Scottish Carboniferous Rocks and their equivalents on the English side of the Border. Little by little this misconception is being corrected, and it is to be hoped that, in time, at any rate, everyone will be agreed in regard to all the essential points concerned. The chief mistake arose through the belief (which never rested upon any secure foundation) that the so-called "Calciferous Sandstone" represented an older member of the Carboniferous Rocks than occurred in England, and that it was, at all events in its upper parts, the equivalent of the Lower Limestone Shale. That this belief exists even yet may be seen by a reference to the index letters on the Geological Survey maps, on which d^1 is used for the Lower Limestone Shale on the English maps, and for the "Calciferous Sandstone" up to where the chief bands of marine limestone come in, on the Scottish Survey maps, for the other. Yet as far back as 1874 appears a statement by myself in the *Quarterly Journal of the Geological Society* that the "Calciferous Sandstone" is, at least in part, the equivalent in time of the lower part of the Mountain Limestone. All subsequent work upon these rocks has helped to confirm that statement; and, to make the matter much more certain, there appeared a paper by my late colleague, Mr. William Gunn, in which he showed that the principal limestones seen on the coasts of the South-East of Scotland belong to the Yoredale Rocks, the d^3 of the Geological Survey of England. I can fully confirm Mr. Gunn's conclusions upon this point. The other point upon which some little uncertainty will probably always remain is with regard to the position of the upper part of the Lower Limestone Shale, d^1; I have had to change my views upon this point more than once. The safest plan, therefore, under the circumstances, is to regard the Ballagan Beds as, in the main, contemporaneous with the Lower Limestone Shale, and to leave the upper limit of the equivalents of the Mountain Limestone (as distinguished from the true Yoredale Rocks*) on an undefined horizon near the middle of the Oil Shale Series of the Lothians. [See the comparative sections given in vol. xv, pt. 4, *Proc. Geol. Assoc.* (August, 1897)]. The lines are, at the best, purely artificial ones, and are not drawn upon any evidence soever of either a palæontological or a physical nature. The true and natural limits of the Lower Carboniferous Rocks are, the top of the Cornstones below, and the base of the Millstone Grit above. There is a palæontological break at both ends of the Lower Carboniferous Rocks; but the minor sub-divisions are purely conventional, and, indeed, might be omitted altogether without any serious loss. In dealing, however, with the local development of these rocks it will be convenient to employ geographical terms,

* By this is meant the upper part of the Lower Carboniferous Rocks as developed in Wensleydale (otherwise Yoredale) itself, from the top of the first limestone below the Hardra Limestone to the base of the Millstone Grit.

when these will serve to define clearly which part of the series is meant. The names already in use by my colleagues will serve this purpose very well. They are as follows, the oldest sub-division being placed lowest:—

B.—Upper Carboniferous Rocks (not considered here).

A palæontological break, accompanied by some local unconformity, occurs on this horizon.

A.—Lower Carboniferous Rocks:

Scremerston Limestone Series;
Scremerston Coal-bearing Beds;
The Fell Sandstones;
The Cementstones or Ballagan Beds; which overlie
The Cornstones of the Upper Old Red Sandstone.

The correlation of these with their equivalents in the North of England and the South of Scotland may be seen by reference to the Comparative Sections given at the end of this paper, which is slightly altered from a similar table given in the Handbook to the Long Excursion to Edinburgh, above referred to.

In the period following the close of that in which the Upper Old Red Sandstone was formed, there seem to have been few, if any, intervals during which a return to continental conditions—or, at any rate, to those accompanied by an arid climate—had any place. There is a possible exception to this in the case of the period which ushered in the Upper Carboniferous Rocks, as will be again referred to presently. The predominant conditions appear to have been those of a great delta, with a continental area lying to the north-west, and with deeper sea, in general, in the areas to the south-east. Small areas here and there stood above the sea level as islands—some, evidently, until a considerable subsidence had taken place; but, in general, the prevailing geographical conditions in Scotland throughout Lower Carboniferous times may be said to have been predominantly those of a delta, with occasional subsidences to somewhat deeper water conditions during the later third of the period under consideration.

THE BALLAGAN BEDS.—Those under which these lowest members of the Carboniferous Rocks of Tweedside were formed can easily be made out from even a cursory study of the facts. They appear to have been extensive mud flats, which were maintained at, or near, the sea level by the deposition of mud, silt, and sand, at a rate which nearly always kept pace with the rate of subsidence. Hence large areas often remained exposed for a considerable time to the desiccating influence of the air and the Sun. They may well be likened to those which are found at the present day in the Runn of Cutch. An occasional

subsidence, more rapid than usual, admitted the sea; while local changes in the direction of the currents, or else inequalities of subsidence, isolated small areas of sea-water in one part, or of river-water in another, and left them in that condition while the adjoining parts, perhaps only submerged at spring tides, or after heavy floods from the land, become dry in the Sun. Hence abundant sun-cracks were formed in the beds of clay, and these often became filled up with sand blown into them by the wind from the areas adjoining, and were thus saved from obliteration. An occasional shower pelted the surface of the mud and left its record in the shape of the well-known rain-prints. Areas of sea-water, temporarily cut off in the lagoons, deposited gypsum crystals, and occasionally even rock salt. Indeed, with regard to the latter, some of the very finest pseudomorphs after Rock Salt that have yet been found were recently obtained by Mr. R. Kidston from the Ballagan Beds of Lower Tweedside.

Farther to the south-west, west, and north-west of the area under consideration, deeper—and certainly clearer—water conditions occasionally occurred, and during these marine intervals bands of fossiliferous marine limestone were formed. Those occurring in these rocks to the south-west—to wit, in Liddesdale—abound in marine brachiopoda and other fossils indicative of at least occasional thalassic conditions. Nevertheless, as the accompanying sections will demonstrate, these rocks were not deposited in the area now represented by the west side of the Lake District. Several other areas, including what is now the south-western part of the Pentland Hills and the eastern half of Fife, also stood long above the sea. In the case of Fife we find that a steeply-sloping shore, formed of the Upper Old Red Sandstone, presented a bank against which Lower Carboniferous Rocks did not begin to be deposited until a late period in the history of that formation. What conditions obtained towards the south-east must remain a matter for pure conjecture; but as marine conditions prevailed throughout Devonian times in what is now Western Europe, there is no reason to think that the Lower Carboniferous period was one of shallower water there.

Soon after the advent of these conditions which have just now been likened to those occurring in the Runn of Cutch, some small volcanic outbursts commenced in these parts, and floods of basalt lavas, which form the well-known "Kelso Traps," overspread parts of the lagoons. None of the flows are of any great thickness, though the area covered may well have amounted to a few hundred square miles. Tuffs are of rare occurrence. But there are some beds of impure cherty limestone associated with these traps in a few localities which look as if they might represent deposits of geyserite. Cherty limestones of much the same character occur in association with the volcanic rocks of Arthur's Seat, of the Bathgate Hills in Linlithgowshire, and with those of North

Berwick. At the last-mentioned locality a very remarkable band is exposed between tide marks on the shore at North Berwick, opposite the eastern end of the Golf Links. The rock specially under notice here is seen, and has long been quarried for building purposes at Carham, Haddon, and Sprouston, on the Tweed. Boulders of it occur here and there in many parts of the district nearer the North Sea, and one of these, near Flodden, forms the megalith known as "The King's Stone." No traces of fossils appear on its weathered surface. It may well have been carried to near its present position by land-ice during the Age of Snow.

Various sills of trachytic rocks, and others of a more basic character, appear to have been intruded at, or about, the period when the Kelso Traps were being laid down. They form important features in the scenery in places.

The volcanic outbreak represented by the "Kelso traps" appears to be of somewhat older date than the volcanic rocks of Arthur's Seat. However this may be, there was a return to the former conditions shortly after the lava just mentioned had been poured out. The conditions appear to have been favourable for the maintenance of shallow water and lagoon conditions for a period of considerable length. Hence the deposition of thin films of mud, silt, and sand in very shallow water appears to have kept pace almost exactly with subsidence, until a thickness of more than two thousand feet of materials had been accumulated. It is quite clear that undercutting of the newly-formed rocks, and re-arrangement of the materials, took place repeatedly as the streams changed their courses from time to time. The more arenaceous bands in the Ballagan Beds of Lower Tweedside furnish abundant evidence relating to this part of their history, as may be well seen in the sections of these rocks exposed on the banks of the lower part of the River Till, and especially near Twizel Castle.

From the occurrence of bands of marine limestone on this horizon in Liddesdale, it is evident either that the subsidences there were intermittent, and that they carried the surface down to a much greater depth at each move, or else that the depth all through was greater there than in the area specially under consideration. This factor has to be taken into account in dealing with the palæontology of these rocks, especially when the peculiar fish-fauna of the Liddesdale area (which appears to be found nowhere else) is being taken into account.

THE FELL SANDSTONES.—After a considerable thickness of clays and shales with cementstones and bands of flagstone had accumulated, the conditions appear to have changed for the time being, and other types of sediment were deposited. The dominant one at this stage consisted of sand and occasional beds of gravel. This does not indicate much more than a seaward advance of the middle part of the delta, due to the fact that deposition had got

ahead of subsidence. Hence it resulted that sand and occasional banks of well-rolled pebbles of milky quartz began to be spread out over the area where previously the dominant type of deposit had been of an argillaceous character. It was under these conditions that the materials which now constitute the Fell Sandstones were formed. Calcareous matter, sometimes taking a concretionary form, sometimes deposited as impure sandy limestones, continued to be deposited; and there is evidence in the sun-cracked surface of some of the beds, as well as in the colouration noticeable in the clays, that shallow waters and lagoons were frequently present. The conditions oscillated between those of lagoons, half-dried flats, and sand-banks of estuarine origin, while the land subsided to the extent of another six hundred feet, which is the average thickness of the Fell Sandstones in the parts of the Borderland under notice. Remains of plants occur frequently in these rocks, but coal seams are of rare occurrence, and, indeed, may be said to be absent altogether.

THE SCREMERSTON COAL SERIES.—In the stage of deposition following that of the Fell Sandstones, there is clear evidence of somewhat more strongly marked changes of physical conditions. The difference in the resulting strata may be attributed to the influence of oscillations of level, with a net result of a movement downward. Thus the seaward front of the area of deposit tended to advance while the land was stationary, and to retreat landward as the sloping surface was lowered beneath the waves. It appears to me that the land sometimes rose again after one of the more decided movements of depression, seeing that sun-cracked surfaces are of by no means uncommon occurrence within a few feet above or below bands of rocks whose fossils indicate deposition within water of moderate, or even of considerable, depth. In reflecting upon the peculiar character of the rocks on the horizon now under consideration, it is well to remember that clear water (and, I think, deep water) marine limestones were certainly in process of formation in the areas to the south and south-west. Ninety miles south of Berwick a thick mass of pure marine limestone, quite devoid of any but the slightest trace of matter of terrigenous origin, represents the deposit which is contemporaneous with the rocks whose origin is under consideration. Likewise, it is well to remember that the percentage of coarser terrigenous material on this horizon as compared with finer, steadily increases as the rocks trend towards the north-west. And it is also in this direction that we find more frequently recurring evidences of volcanic action. It appears to be tolerably certain, therefore, that the old continent whose waste furnished the materials of the Lower Carboniferous Rocks of terrigenous origin, lay to the north-west of where the valley of the Tweed is now, and, of course, therefore, that the open sea all through the period in question lay to the south and the south-east of this part.

One of the characteristics of the strata which overlie the Fell Sandstone is the occurrence in them of several seams of good, workable coal. It may be well to remark here that these coal-seams which form the Scremerston Coals are on the same geological platform as the Oil Shale Series of the Lothians, and, furthermore, that it is also on this horizon that the chief manifestations of volcanic action in the Central Valley of Scotland occur. In discussing the mode of formation of the Scremerston Coal Series, as a whole, it is perhaps safest to repeat the statement above made, that the period during which these rocks were formed was one characterised by frequent oscillations of level. I do not feel quite justified here in stating that the coal seams were formed (as I believe they were) in clear water, on the lateral margins of the areas of deposit of inorganic sediments, seeing that in all probability other geologists might regard the statement as being of far too heterodox a character to be trusted. Those who wish to ascertain my views on this much-disputed point might read the paper "On some Modes of Formation of Coal Seams," *Geol. Mag.* III, vi, p. 308 (1889), and *Proc. Roy. Phys. Soc.*, x, p. 97 (1889).

As a negative feature not quite devoid of interest in the present connection the statement may be repeated that there are no traces in any part of the district within a long distance of Berwick of any volcanic rocks formed contemporaneously with the Scremerston Coals.

THE SCREMERSTON LIMESTONES.—The rocks which succeed the subdivision just noticed are characterised by the occurrence in them of bands of limestone of marine origin. Mr. Gunn has shown that this "Calcareous Division," as developed near Berwick, includes some representatives of the upper part of the Mountain Limestone of the areas to the south, though it consists mainly of the Yoredale Rocks properly so called.*

In regard to the relationship of the rocks on this horizon in Tweedside to those in Westmoreland a few words here must suffice, and I must leave the reader who wishes to know more about these points to read the "Explanation" of Sheet 102 S.E.; or, better still, my article on the "Geological History of Cumberland" in the Victoria County History relating to that part. The chief points are connected with the fact that the marine limestones tend to be split up by bands of shale, and these enlarge and pass into sandstone, as a given horizon is followed from the south northward. The change is progressive, and it affects the beds in succession from below upward. Hence the lower limestones are the earliest to disappear and to be replaced

* I must protest against the practice that has lately come into vogue of taking the Clitheroe district as the typical one for these rocks. The true Yoredale Rocks are there partly represented by the top of the Clitheroe Limestone; while the upper part of the rocks there referred to the Yoredales may represent some strata newer than the Yoredale Rocks of the typical area, and still be older than the Millstone Grit

by deposits of terrigenous origin, while the higher beds persist the longest. Hence, in tracing the beds of limestone from Westmorland through Cumberland and Northumberland, past Berwick to the Lothians, we find certain bands of limestone which are represented by mere traces at Berwick, but which assume very much more important dimensions in the area to the south, and which die away, one after the other, the lowest in each area being the first to go—until, by the time they reach the valley of the Forth, all but the highest of the limestones have passed laterally, first into shales, and finally into sandstones. A reference to the comparative sections issued with this Handbook will serve to make this point clearer. The line between the calcareous division and the noncalcareous occupies a different position in different districts, and is much higher in the basin of the Forth than it is in the basin of the Tweed.

A curious and very interesting palæontological fact comes into prominence in studying the fossils from these rocks. Of palæontological zones of any value traces have long been sought in the Lower Carboniferous Rocks, and have been sought in vain. Apparently none exist. I have ventured elsewhere to attribute this to the fact that the *surface* waters of the sea during Lower Carboniferous times were equable in temperature from the commencement to the close of that period—that is to say, the surface temperature of the sea did not vary much at any time from a given mean, which mean was the *optimum* for the plankton representing the fry of the marine invertebrata of the period. What, however, we do find is that, though the species persist throughout, the individuals of a large number of these species exhibit a considerable variation in size, when those from a northern district are compared with the same species obtained farther south. Let any one make a comparison, for instance, between almost any group of invertebrates, especially the Mollusca and the Brachiopoda from the Lothians and a number of individuals of the same species from, say, Clitheroe. The latter have quite four times the volume of the former. Even when the comparison is made between the fossils found in the limestones at Dunbar and those found in their equivalent strata at Scremerston, the remarkable difference in size is at once apparent. We should probably not err greatly in such a case if we attribute the difference to the influence of warmer water and a more abundant food supply in the case of the more southern habitat than was the case with their more boreal representatives. If this is the correct explanation of the facts it affords one of very few illustrations of the effect of latitude upon animal life which have yet been met with in the records of the Past; and it may fittingly be compared in this respect with the general similarity of the fauna of the Jurassic Rocks of, say, Caithness, with those of the South Coast of England.

So far as the palæontology of the Lower Carboniferous Rocks is concerned the only other remark that need be made is that, speaking in general terms, in all the rocks which have been formed under the same conditions the same assemblage of species occurs throughout. Thus the fauna of a limestone from near the base of the series differs but little from that of a similar bed from near the top. So, too, with the shales, as well as with the sandstones.

Rocks of Upper Carboniferous age do not occur near Berwick, and therefore it is not necessary to do more than to remark that, although it is practically impossible to "zone" the Lower Carboniferous Rocks by means of their fossils, yet, directly the Upper Carboniferous Rocks are under examination, we are struck with the abruptness of the change which characterises both their flora and their fauna. Dr. Traquair, with regard to the fishes, and Mr. Kidston with the plants, are equally emphatic upon this point. I feel sure, too, that the physical break between the two is much greater than geologists in general have hitherto seemed disposed to admit. In the Craven area, in particular, it seems to me that the base of the Upper Carboniferous Rocks lies transgressively across, or oversteps, the edges of strata of Lower Carboniferous age which are widely separated in time. Moreover, the presence of abundant fragments of felspar, which occur so commonly in the lower beds of the Millstone Grit, are at least suggestive of there having been a temporary return to the arid conditions which characterised the period when the Upper Old Red Sandstone was in process of formation. Hence there may well have ensued an extensive upheaval and prolonged denudation, as well as a temporary change of climate, at the close of Lower Carboniferous times; and it may well be the case that the palæontological break referred to is due quite as much to these factors as to lapse of time.

THE WHIN SILL.—In the area represented by the basin of the Tweed rocks of the same age and character as the Whin Sill form hardly any prominent feature. It is true that within sight of Berwick, as, for example, near Belford, there are conspicuous crags and other features due to the Whin Sill, and also that the Farne Islands consist almost entirely of this dolerite. All, however, that need be stated here regarding the Whin Sill is that it is, like every other intrusive rock I have yet seen, distinctly REPLACIVE and not displacive in its mode of occurrence: that is to say, it cannot be proved anywhere that the Whin Sill has actually forced asunder the sedimentary rocks within which it was intruded, in such a manner as is so often depicted in diagrams of the so-called "laccolites." So far as the age of the Whin Sill is concerned one may confidently say of it that it is of later date

than the earlier of the disturbances which have affected the Lower Carboniferous Rocks. On the other hand, the Whin Sill in the Farne Islands certainly shows the characteristic staining of ferric oxide which appears nearly everywhere to result from infiltration proceeding from the New Red Rocks. Hence if we can trust this latter evidence (and I think we may), the Whin Sill dates from some time in the very long period that followed the Carboniferous era and preceded that of the New Red.

POST-CARBONIFEROUS DISTURBANCES.—Just as an era of disturbances and denudation set in near the close of the Silurian epoch and continued through the immensely long period of time that intervened between that and the commencement of the Caledonian Old Red, so was it the case with the Carboniferous Rocks. There is abundant evidence in all parts of Britain where these rocks occur that they were folded, faulted, and denuded, to an extent not much inferior to that which has been above referred to as characteristic of the Proterozoic Rocks. It may be said with some measure of truth that most of the denudation from which the Proterozoic Rocks have suffered took place in the interval between the close of the Silurian Period and the commencement of the conditions to which the Caledonian Old Red is due. And with equal truth it may be said that the chief disturbances, and also the chief denudation, from which the Carboniferous Rocks have suffered, took place in the very long interval of time that separates the Deuterozoic Rocks from the oldest of those of the Neozoic age.

THE NEW RED ROCKS.—There cannot be much room for doubt that the New Red Rocks formerly covered most of the area represented by the basin of the Tweed, as was certainly the case with most of, at least, the southern parts of Scotland. As the former presence of the Trias implies also that of the Jurassic Rocks (in exactly the same way as the presence of the Upper Old Red Sandstone implies that of the Lower Carboniferous Rocks), this point is obviously one of considerable importance in relation to the history of the district.

There are, however, no actual outliers of any member of the New Red Series (either of the Lower, or "Permian," or of the Upper, or Trias). The evidence pointing to their former existence here is practically confined to that afforded by the widespread staining of the sandstones and shales of the Carboniferous Rocks, and the equally widespread dolomitisation of the limestones. Scottish geologists are, at last, beginning to recognise the value of this evidence.

LATER CHANGES IN NEOZOIC TIMES.—A period of prolonged subaërial waste, ending with the formation of a base-level, or

perhaps a plain, of marine denudation, followed the close of the Jurassic Period; and the Cretaceous, and, possibly, even newer rocks, were laid down far and wide upon the plain referred to. There is no evidence to show that any British mountains, now existing as such, were left uncovered by these rocks; while, on the other hand, there is much to be said in favour of the view that the final elevation to which those mountains are primarily due took place in Post-Cretaceous times. I have maintained for well on to a quarter of a century that the summit-levels of many of our British mountain tops represent the Pre-Cretaceous plains of marine denudation, upheaved, flexed, and subsequently re-exposed by the removal of the rocks which capped them.

HISTORY OF THE RIVER COURSES.—These remarks are necessary in the present case, because the courses of the greater number of the rivers are explained most satisfactorily by the hypothesis that the rivers commenced to flow over a surface formed of some other rocks than those which are now represented in the district. The rocks in question may have been in part Cretaceous; though there does not appear to have yet been any valid reason advanced why rocks of Tertiary age should not have formed part of the original outer envelope referred to. Nor does there appear to be any good reason for objecting to the view that the river courses, as such, were initiated in late Tertiary times. The fact that a patch of Old Red, or of New Red, as the case may be, occupies the bottom of what is now a valley, may be due simply to the fact that the area in question marks the axis of a synclinal which has affected these rocks, and their presence has helped to guide the river at an early stage in its evolutionary history into coincidence with the axis of the synclinal. Thus it would be more correct to say that a certain river flows in a synclinal fold of the Trias, rather than that the Trias lies in an old river valley, which, therefore, on this latter view, dates from Triassic times.

In this connection it is important to remember that some of the largest valleys in Scotland can be shown to have been excavated entirely in Late-Tertiary times: witness the deep valley of Loch Scridain in Mull, or the grand depression in the Coullin Hills, in which reposes Loch Coruisk; to say nothing of the somewhat doubtful case of Loch Lomond, so often cited in this connection. If long and wide valleys, between three and four thousand feet in depth, have been excavated in very hard rock since Late-Tertiary times, why should the mere size of a valley be cited as proof of its great geological antiquity?

The river channels, having been established in approximately their present courses, were deepened and widened as time went on, sometimes maintaining their original directions with very little change; but in other cases being diverted, severed, or even reversed through the influence of variations of structure and

durability of the rocks which happened to compose the surface at one time or other in their history as they cut their way down through the various envelopes of rock over which their courses lay. I have already dealt with questions of this kind at some length, in relation to the rivers of the Lake District, in the papers mentioned in the footnote,* and the subject does not call for any special treatment here. Apparent difficulties connected with the history of such river-courses as that of the Till, for example, admit of a simple enough explanation if we assume that the rivers in question began to flow in different rocks from those in which their respective courses are now established. Doubtless the Till has been gradually led out of its original way as a result of the river, at an early period in its developmental history, meeting with rocks which became either barriers, or else zones of low elevation, at one part or another of its course.

LATER TERTIARY CHANGES.—It may be taken as proved that the latest phase of volcanic action in Britain took place at a period when many of the broader features of the present landscape had already been, as it were, sketched out. Some, at least, of the larger valleys had already taken on much of their present form and direction, even though the actual surfaces may have been carved out of rocks which have long since been removed by denudation. It was at the earlier part of the period (and much later than the culminating period of volcanic action) that so many of the remarkable basalt dykes which traverse the rocks of Northern Britain were formed.†

It was also during the waning phases of this same volcanic episode that the principal metalliferous veins of Northern Britain received most of their original mineral contents. This appears to be the case with most veins of lead ore. There are not many such in the area here specially under consideration. A few veins of copper ore occur at the foot of the Lammermoors, not far from Duns. The hæmatite veins appear to be, in all cases, much older than these, and to date from the close of Triassic times.

THE AGE OF SNOW.—The history of the Age of Snow calls for some remarks here. Briefly stated, that history may be given as follows:—The present valley-system, and all the larger surface-features, had already been shaped by subaërial denudation, possibly as early as the Pliocene Period, into a form not essentially different from what they have now. About the close of that time it seems probable that Britain, as a whole, stood at a higher level

* The History of the River Eden and the Rivers adjacent, *Trans. Cumb. and West. Assoc.*, No. xiv, p. 73. Geological History of "The Eden Valley," *Proc. Geol. Assoc.* (1889), p. 53. The Physical History of Greystoke Park and the Valley of the Petteril, *Trans. Cumb. and West. Assoc.*

† It is not clear that any of these dykes are "intrusive" in the sense commonly understood by that term: many of them are certainly replacive—perhaps they all are.

than it does at the present day, so that what is now the North Sea was then a lowland plain, through which the Rhine flowed northward, and may have entered the Atlantic on the northern side of Shetland. The Tweed, as well as the other rivers on the eastern side of Britain, then formed tributaries of the Rhine. The western margin of Britain, under these conditions, may have coincided with the present 100 fathom line. The facts appear to me to suggest that the so-called "Gulf Stream" then brought large quantities of aqueous vapour to the coasts of Britain and Scandinavia, much as it does to-day. But, with an increasing elevation of these lands above the sea level, the precipitation, instead of usually taking the form of rain, as it does now, began to fall more frequently as snow; and, as the elevation of the British-Scandinavian axis proceeded, the result came about that the whole of the aqueous vapour distilled by the Sun's rays from the surface of the Atlantic, and drifted hither by the winds, was deposited in the form of snow. All that is needed to bring about what are usually called "glacial" (but which had better be termed "nivosal") conditions, is a copious supply of aqueous vapour, winds to drift it in a certain direction, mountain tops to congeal it into snow, and such conditions on the lowlands as to permit of rather more snow being left each year than the summer's heat would suffice to melt. It is fallacious to suppose that a low temperature is indispensable to bring about these nivosal conditions. There is no reason why the average annual temperature of Britain then should be many degrees lower than it is at present. A brief consideration of these points will suffice to show that a differential uplift along a zone passing through Scandinavia and the northern parts of the British Isles while the "Gulf Stream" was in full operation, would furnish all the conditions needed for bringing about an Age of Snow; and if the uplift reached its maximum along this axis in Central Scandinavia, the geographical conditions would be such as would suffice to account for nearly all the facts known in connection with the Age of Snow.

There is no evidence of a nature that would satisfy every geologist regarding the time that has elapsed since these nivosal conditions began. But there cannot be much doubt, if we are guided by the evidence presented by the Later Pliocene rocks of East Anglia, that these rocks mark the earlier stages of the conditions which culminated in the Age of Snow. In that case we seem to have data from which we may form an approximate estimate of the period in question. It appears to be generally admitted now that both Vesuvius and Etna have come into existence within the same period of time as that which separates the commencement of the Later Pliocene period from the present day. If we assume, as a very moderate estimate for the growth of Etna, that, taking it as a whole, it has required three hundred years for the accumulation of each foot, this estimate

gives us a period of at least three million years. Yet the amount of change in the organic world that has ensued since Etna started into existence is so trifling that it would not be taken into account if we were dealing with the palæontology of some of the rocks belonging to the older parts of the series.*

Although the changes in the organic world since the close of the Newer Pliocene Period are comparatively insignificant in amount, the case is far otherwise when we are dealing with the changes that have taken place upon the surface of the land within the period under consideration.

An enormous amount of rock material, much of it being, of course, rock that had been already decomposed by subaërial agencies, was removed by the ice during the Age of Snow. It may be said, indeed, in general terms, that there is hardly a single feature which forms a component of the landscape in Lower Tweedside, which, in one way or another, does not owe much of its present configuration to the action of the ice which moved over the whole district throughout the greater part of the Age of Snow. The chief erosion was accomplished in the valleys, which were irregularly deepened and widened in a manner quite unlike what could have resulted from any erosion by the action of rain and rivers. But one of the features which impresses a peculiar character upon the landscape in the lowland areas of Tweedside is the great system of glacial furrows to which so many references have been made by students of glacial geology. The whole surface of the country, over hundreds of square miles, consists of an assemblage of rudely-parallel ridges and furrows, which preserve a common direction over large tracts of country. Some of these ridges, it is true, consist of eskers; while a few others are exteriorly composed of boulder clay. But, as a whole, they fundamentally consist of solid rock. That these are really of glacial origin, and not due to the erosive action of running water under any conditions, is rendered sufficiently evident by the fact that glacial markings occur within them, and not at all uncommonly they do so at the lowest part of the hollow. Doubtless it has been the large size of these furrows which has misled geologists in their attempts at accounting for the origin of these remarkable features.

When the load of ice had increased to its maximum, a subsidence of the land commenced. In consequence of this the mountain tops were gradually lowered, the sea was admitted where there had formerly been land, rain began to fall where previously it had snowed, and the supply of snow which fed the glacier-ice was cut off at its source. The stony ice then melted away as it stood, leaving boulder clays and eskers (both englacially formed) as the "sediment" of the ice sheet. So, by degrees, and in the course, it may well be, of many thousands of

* Origin of the British Flora, *Proc. Botanical Society of Edin.*, 1902, p. 234.

years, the surface of the land was left very much as we see it to-day.

When the subsidence reached its lowest point, which may well have been as much as a hundred and fifty or even two hundred feet below its present level, there appears to have been much floating ice about the lately-filled North Sea. Much of this ice found its way up the sea inlets, and as the ice melted it dropped its stony burden upon the sea floor. Fragments of chalk, chalk flints, pieces of metamorphic and plutonic rocks foreign to the district, were left by this means even in such areas as the lower part of the valley of the Tweed. The boulder clay on the banks of that river a short distance above Berwick Station, described by Mr. Gunn, is, I think, a deposit formed under the conditions described.

There is every reason for believing that the period following that when the submergence took place may have dated as far back as some fifteen or even twenty thousand years. Small glaciers still grew up inland, and there may well have been some of them even in the heart of the Cheviots. If one may judge of what took place by the records of those left in the glens of the Southern Highlands of Scotland, these glaciers showed two periods of activity. In some of the earlier of these the valley glaciers extended several miles outward from their starting point, and long remained thus because supply and waste were equal in amount. After this phase there followed a period during which the rate of melting of the ice much exceeded the supply furnished by the snowfall, and a somewhat rapid retreat of several miles ensued. Then came a second period when the supply and waste remained nicely balanced for a long time, and an inner group of moraines was formed. Finally snow ceased to fall (or, rather, to remain) in quantities sufficient for the growth of glaciers, and the present state of things came into being.

While these events were in progress, the maritime areas were being affected in a different way. The land rose with a start every now and then, and the intervals between each move were of sufficient length to permit of the sea carving well-marked beaches, and leaving other tokens of what was being done upon the land adjacent. At the same time widespread deposits of gravel and other alluvial matter were left on the banks of the rivers. These correspond in both their form and in the date of their formation, with the raised beaches just referred to. Then, as the land rose by successive uplifts towards its present level, successively lower terraces were cut by the rivers, whose increased velocity, gained by each uprise, enabled them to accomplish this readily; and in the meantime the sea carved lower and lower shelves upon its margin, and left old sea-stacks and sea caverns high and dry, until the latest uprise (which took place prior to the Roman invasion of Britain) brought the land up to the level it has at present. It

was under these conditions that both the maritime denes and the remarkable river terraces of Lower Tweedside were formed.

STRATIGRAPHICAL GEOLOGY.

The foregoing historical account of Lower Tweedside should suffice to make the broader features of the geology of that part sufficiently clear. But a brief outline of the stratigraphy of the district, which may be read concurrently with a study of the sections, may help to extend what has been stated in the foregoing pages.

The Ordovician Rocks form but a small part of the area, and, therefore, although their interest, historically regarded, is very considerable, they may be left without further mention here.

Rocks of Silurian age may be said to occur within five areas in the district under description. One of these, and the principal one, is part of the main area of the Scottish Southern Uplands. Another, which is separated from the former only by a narrow band of the Upper Old Red Sandstone, forms the southern part of the Lammermuir Hills. The third lies to the east of this, and its coastal margin forms the magnificent line of cliffs extending south-eastward from the Siccar Point to St. Abb's Head. The fourth forms a triangular area which extends southward from Eyemouth to just outside the northern suburbs of Berwick. It forms the grand line of cliffs which extend northward from Burnmouth. Its south-western border coincides with a large fault which brings the Cementstones and the Fell Sandstones into contact with it on the north side of the Tweed about a mile west of Berwick. The fifth, and smallest, lies somewhat beyond the area specially under notice, and rises to the surface from beneath the Cheviot Andesites and other rocks of later age, on the south-west flank of the Cheviot Hills.

Everywhere in these districts the Silurian Rocks are highly convoluted, but they are rarely or never cleaved. They are frequently traversed by dykes of porphyrite. The closest folds, which are usually isoclines, lie in the north-western part of the area, where, it appears safe to assume, the main axes of uplift, and chief zones of compression, were situated during the early Devonian period. Most of the Silurian Rocks in this area belong to the Valentian and Salopian sub-divisions.

The Caledonian Old Red, it must be remembered, is separated from the Proterozoic Rocks by one of the most important unconformities in the whole geological series. It lies, in fact, on the upturned and denuded edges of every rock older than itself. Not only that, but the chief disturbances which have affected the older rocks are of prior date to any part of this series The basement bed is sometimes a conglomerate, with tuffs and subordinate

sandstones in its higher parts. Rocks of this kind, which are of the nature of outliers, are still to be found about Reston, Coldingham, St. Abb's Head, and Eyemouth. More generally, however, the volcanic series which succeeds the conglomerate in time, lies directly upon the older rocks. The chief mass of these is left in the Cheviot Hills; but an important outlier of that age occurs at St. Abb's Head and Coldingham Shore, while some eruptive rocks referable to the same horizon are to be seen at Eyemouth. Three masses of granite, which may be nearly of the same age as the later lavas of this series, are to be seen near Berwick. The larger of these has risen through the Cheviot Andesites, and may be regarded as forming the core of the Cheviots; another forms Cockburn Law, north of Duns. A third lies in the heart of the Lammermuir Hills, still within the basin of the Tweed, but in a position not easily reached. This latter forms Priestlaw, which consists of one of the masses of granite formerly regarded as of metamorphic origin. Porphyrite dykes occur in many places, and there is at least one dyke of mica-trap at St. Abb's Head. None of these rocks have been affected by terrestrial movements to any great extent in the district under notice.

The Upper Old Red succeeds the formation just mentioned, and does so with a violent unconformity. To realise the full extent of this great break one must bear in mind the fact that the Caledonian Old Red is certainly many thousands of feet in thickness—even though the figures given by some writers may err very greatly on the side of excess in this respect. In addition to this sub-division there is the Orcadian Old Red, also many thousands of feet in thickness, which is certainly as a whole newer than the Caledonian Old Red, and across the edge also of which the Upper Old Red lies unconformably. These facts do not admit of question; and yet they do not seem to be generally known.

In the Tweedside district remains of the Upper Old Red Sandstone extend in a continuous strip from Dunbar southward past Duns, Greenlaw, Earlstone, Melrose, Jedburgh, to some distance south of the western margin of the Cheviots. A branch from this strip runs eastward past Chirnside to within a short distance of Berwick, where it is cut off by a powerful fault above referred to. On the eastern flanks of the Cheviots the Upper Old Red occurs here and there, but that only to a small extent. Some trachytic rocks intrusive in this form conspicuous features in the landscape, especially near Duns, and at both the Black Hill of Earlston and the Eildon Hills, near Melrose.

Wherever the Upper Old Red occurs it appears to have been followed by the Carboniferous Rocks, though not in every case with perfect conformability.

A wide-spread bed (or beds) of basalt lava and occasional beds of tuff locally occur close down upon the Upper Old Red. These can be traced southward from Greenlaw across the Tweed west

of Kelso to the northern flank of the Cheviots; and also northward to Duns. A similar bed is seen here and there also on, or about, this horizon, nearly all the way south-westward as far as the north bank of the Solway.

A band of (what I take to be) geyserite occurs close above the basalt, especially at Carham, on the Tweed above Coldstream. It is chiefly of interest as being the parent rock of a large number of boulders which are strewn about Lower Tweedside. It is of interest also because part of its colloidal silica has passed into a red chert which resembles carnelian in places.

The succeeding Ballagan Beds* cover a wide area around the River Tweed, where they form the surface over quite a hundred and twenty square miles. Their prevailing dip is at a small angle eastward, so that higher beds come on as the rocks trend from, say, Greenlaw to Holy Island, or from The Cheviot in the direction of Alnwick. They consist of a thick mass of shale and clays with subordinate beds of more or less calcareous flagstone and soft sandstone, and with some few bands of impure limestone, interstratified with the sandstones and shales near the top of the series. These latter are well seen at Ross Point, near Burnmouth. A curious feature in the sandstones is the occurrence of great orbicular concretions. Resorted material is of frequent occurrence in the lower beds, and sun-cracks, casts of rock salt, and veins of gypsum may often be met with.

The Fell Sandstones occur chiefly on the Northumberland side of the Tweed, and mostly in the angle enclosed between the River Till and the Tweed just above Berwick. They do not give rise to any conspicuous features there, as they do on the southern flanks of the Cheviot; but the harder beds are apt to form low escarpments, and even small hills in a few cases. They can be well seen at Tweedmouth and Ord, and on the north bank of the Tweed, below St. Mary's Convent School, and here and there near both the Royal Border Bridge and the Old Bridge. Northward of Berwick they are cut out by powerful faults. The "Duddo Stones" are megaliths of this rock.

The Scremerston Coal Series lies almost entirely on the Northumberland side of the Tweed, and extends southward from Tweedmouth and Spittal past the eastern side of the Till for a considerable distance. These rocks are indicated at the surface by a number of small collieries. It is perhaps as well to repeat that the Scremerston Coals lie on the horizon of the upper half of the Mountain Limestone and the lower fifth of the Yoredale Rocks. Furthermore, they are on the same horizon as the Oi Shales of the Lothians, and, therefore contemporaneous with the great Lower Carboniferous volcanic series of Fife and the Lothians. The reader will find these correlations given in the sections which were issued with the "Handbook to the Geology

* Also known as Lower Twedian, Cement Stones, and Lower Limestone Shales.

of Edinburgh," which was written for the Geologists' Association Long Excursion there. In a slightly modified form they are given again here.

A strip of the Scremerston Coal Series passes along the coast northward from Berwick; but is mainly concealed beneath the newer rocks of Lower Carboniferous age, which will be noticed more fully presently. This strip is cut off on the west by a fault. The best section in the Scremerston Coals is to be seen along the coast near the place of that name, south of Berwick.

The Limestone Series, most of which forms the upper part of the true Yoredale Rocks, is characterised by the occurrence in it of some dozen or more bands of marine limestone. These are remarkably persistent in the area to the south, though they die out one after another from the lowest upward as they trend in the opposite direction. Mr. Gunn's important papers on these beds should be consulted by those who wish for fuller information.

On the south side of Berwick the limestones strike south-eastward for a mile or so. They are very well seen on and near the coast as far as Scremerston itself, south of which they are hidden beneath superficial deposits. Inland the strike changes, and becomes south-westerly for a few miles; and then swings round so as to conform in a general way to the margins of the Cheviot Hills away from which the succeeding Lower Carboniferous Rocks everywhere dip. But they are so much broken and disturbed by faults in the country about Lowick that no general description could convey impressions of their lie which would be of any use for the purpose for which this paper is intended. The Scremerston Limestones have yielded an extensive suite of fossils, lists of which are given in the "Survey Memoirs." Mr. John Bishop, of Berwick, has long collected diligently from them.

At Berwick itself the upper limestones are very well seen at several places on the shore. Northward of the town they are more or less faulted. The Eelwell Limestone is seen west of the Pier, and it also forms the Ladies' Skerrs, which are well known to visitors on account of the singularly twisted form their strike assumes on the shore. It is also seen at the Fisherman's Haven. The rocks on the shore are much faulted and disturbed, but Mr. Gunn has been able to unravel some of the complications. The rocks, on the whole, rise as they trend northward, so that beds older than the Eelwell Limestone appear as the coast-line is followed in the direction of Burnmouth. But the five thin limestones next below the Eelwell Limestone, are not very well seen anywhere near Berwick. They appear in the Tweed at low water, Mr. Gunn says, between the Ness Gate and the Pier at Berwick. Going along the coast north of the town the fine sea-caverns, eroded by the waves in the sandstone, form very striking features. The Burgess Cove is one of these, which has been

shaped in a bed of sandstone whose true position is near the Scremerston Coal Series, and is the equivalent in time of, perhaps, the Melmerby Scar Limestone of Cumberland. The Oxford Limestone, which Mr. Gunn thought might be the Hardra Limestone of Phillips's typical section, is seen on the cliff at Sharper Head. Sharper Head itself consists of the sandstone between

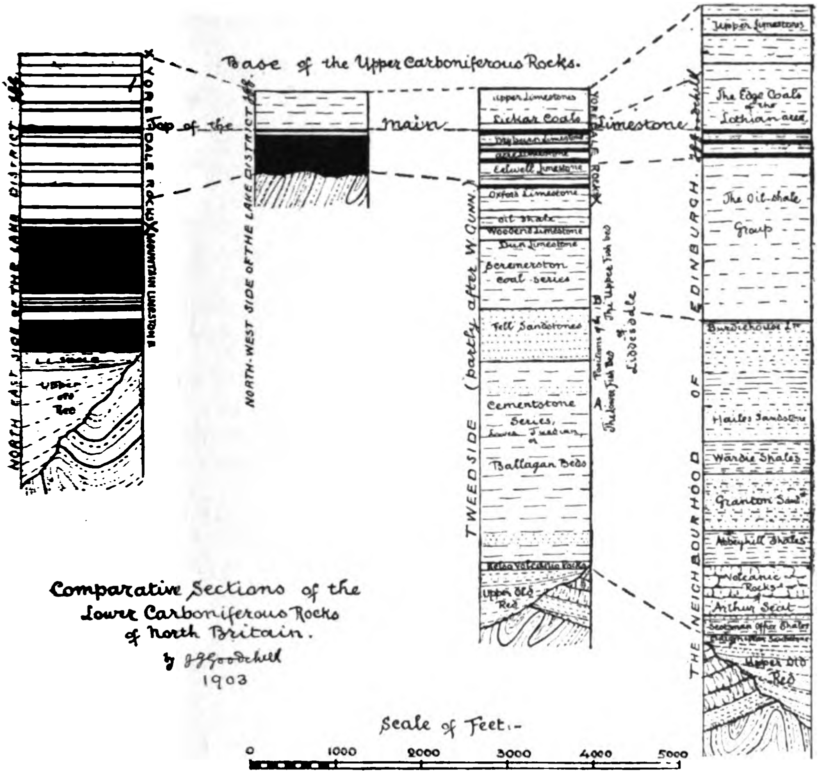

FIG. 3.—SECTIONS ILLUSTRATING VARIATIONS IN THICKNESS AND MINERAL CHARACTER OF THE LOWER CARBONIFEROUS ROCKS; WITH ESPECIAL REFERENCE TO THOSE ROCKS NEAR BERWICK.

this limestone and the Greencies Coal. It lies only a few feet above the base line of the Yoredale Rocks. Berwick is the last place going north where this can be made out.*

Two of the thin limestones which represent the higher beds of the Mountain Limestone of Phillips are the Woodend and the

* The account of the rocks on the coast north of Berwick is chiefly from Mr. Gunn's papers; but I am responsible for some of the statements.—J. G. G.

Dun Limestones. The former is seen 700 yards north of the Burgess Cove, and the latter at St. John's Haven, as well as on the foreshore south of Spittal, but only at low water. Below these comes the thick sandstone of Marshall Meadows, which forms a considerable cliff on the coast north of Berwick. This overlies a coal seam which Mr. Gunn thought might be either the "Robies" or the "Fawcett" Coal. North of Marshall Meadows the boundary faults cause so much confusion that it is almost useless to try to make out the succession.

The section just described is one of considerable importance, as Mr. Gunn's work upon it has given the only satisfactory clue to the true positions of the beds which form the "Carboniferous Limestone Series" of Scotland. The Eelwell Limestones form the lowest of these latter, whence it will be perfectly evident that the so-called "Calciferous Sandstone"* consists in its upper part of the basement beds of the Yoredale Rocks.

As the coast section north of Berwick is both difficult to understand, and is also of great interest, three sections across it are given here. A study of these, with the comparative sections before one, ought to suffice to make their several geological relationships quite clear.

The Whin Sill appears to have died out a few miles to the south of Berwick, after extending through a tract of country many hundreds of square miles in extent. It forms conspicuous crags near Belford, and appears at intervals for about seven miles to the north-west of that town. It is, of course, what is commonly understood by an "intrusive" sheet, and it consists of dolerite. The age is pre-Triassic or post-Carboniferous. It is the Whin Sill which, extending to the coast at Budle Point, forms the rock upon which Bamburgh Castle is built, and which, extending out to sea, forms nearly the whole of the picturesque group of rocks known as the Farne Islands, so much celebrated as bird stations, and equally so in connection with many stirring tales of misadventure at sea.

Characteristic examples of the staining and other alterations of the Carboniferous Rocks, which I have attributed to infiltration from the New Red, are to be seen in many places near Berwick.

The castle at Holy Island is situated upon the outcrop of a basalt dyke which ranges nearly east and west. It is probably a continuation of one of the two which can be traced from near Holy Island in westerly directions for many miles, and across the Tweed near Coldstream. These dykes appear to be newer than the faults and other disturbances, and they may therefore be of Tertiary age.

Glacial deposits do not call for any special remark. Boulders

* The rocks appear to have been named on the lucus a non lucendo principle, for calcareous matter in the typical areas of the "Calciferous Sandstone" is conspicuous by its absence, and the rocks consist largely of shale.

of far-travelled rocks occur, but none of them are of any very special interest. The megalith known as "The King's Seat," near Pallinsburn, is, however, of interest as an erratic which has probably originated at Carham. It appears to be part of what I have regarded as geyserite there.

Drumlins and eskers abound, and have formed the subject of many discussions by the late Milne Home and other Scottish geologists.*

Boulder clay which may date from the submergence, cccurs on the banks of the Tweed just above the station at Berwick. It was described by Mr. Gunn in the *Proc. Berw. Nat. Club*, vol. x, p. 540. The clay contains many far-travelled rocks, and also fragments of shells.

Excellent examples of upraised river-terraces, as well as of raised beaches, are of common occurrence. The terraces of the Tweed have been alluded to, and their meaning discussed by many writers, and especially by Milne Home.

In conclusion I wish to express my thanks to Mr. Clough for his friendly aid, to Commander Norman, R.N., of Berwick, for introductions to much that is of interest in the geology of Lower Tweedside, and to Mr. George Bolam, F.Z.S., for help in connection with the visit of the Association.

The following publications relating to the district under consideration may be noticed:

The Geological Survey Maps and Explanations of Sheets 108, 109, 110, by Messrs. Clough, Gunn, and Miller. Mr. Gunn's papers in the *Trans. of the Berwickshire Naturalists' Club*, vol. xvi, No. 111 (1899), p. 313; *Trans. Geol. Soc. Edin.*, vol. vii, pt. iv, p. 361; and the *Geological Magazine*. The Maps and Explanation of the Geological Survey of Scotland, Sheets 25, 26, 33, 34.

The Geological Survey Map of Scotland, on the scale of 10 miles to the inch, published by John Bartholomew & Co., Edinburgh, affords a very excellent general view of the geological structure of the whole of the district to be visited by the Association. Amongst other publications relating to the country around Berwick may be mentioned Lebour's *Geology of Northumberland*, and the Geological Map of that county by the same author; Hugh Miller's article on "Northumberland" in the 9th edition of the *Encyclopædia Britannica*; Stevenson's article on "Cockburn Law" in the *Trans. Roy. Soc. Edin.*, for 1849. An excellent outline of the Geology of the Cheviots, by James Geikie, appeared in *Good Words*, and is reprinted in his "Fragments of Earth and Ore." Tate's article in

* See also "The Bedshiel Kaim," by J. G. G., *Proc. Berwickshire Nat. Club*, for 1898, p. 296.

the *Proc. Berw. Nat. Club*, vol. iv, is of interest, as also is Hugh Miller's paper "On the Classification of the Carboniferous Limestone Series, Northumbrian Type," read before Section C at the meeting of the British Association, 1887; *Proc. Berw. Nat. Club*, vol. xii, p. 116.

The Petrography of the Cheviot Hills has been treated of by several authors, especially by J. J. H. Teall, F.R.S., *Geol. Mag.*, Dec. 2, vol. x, pp. 100, 145, 252, 344; Dec. 3, vol. ii, pp. 106-121; and by Kynaston, *Trans. Edin. Geol. Soc.*, vol. vii, pt. iv, pp. 390-415. Mr. Clough's Memoirs are also of great importance, and especially the one on "The Cheviot Hills" (*Mem. Geol. Survey.*). Prof. Watts' contributions to the Memoirs relating to sheet 110 S.W. should also be consulted.

EXCURSION TO GRAYS.

MARCH 21ST, 1903.

Director: T. I. POCOCK, M.A., of H.M. Geological Survey.

Excursion Secretary: A. E. SALTER, B.Sc., F.G.S.

THE party met at the railway station at Grays on the afternoon of March 21st, 1903, and walked to the top of one of the chalk quarries, where recent excavations have exposed a good section of the Thanet Sand overlaid by river gravel. The bed of green-coated flints at the base of the Thanet Sand was well seen all round the head of the quarry. It was about six inches thick, and had a somewhat wavy surface. The river gravel at the top is an outlier of the high terrace gravel of the Thames valley, which rests on a platform about 100 feet above ordnance datum. In one place a good instance of the effect of subterranean erosion was observed. A deep hollow or "pipe" had been excavated in the chalk by the solvent action of carbonated water percolating from the surface. Into this hollow the Thanet Sand had subsided, carrying with it the river gravel. Several small faults were caused

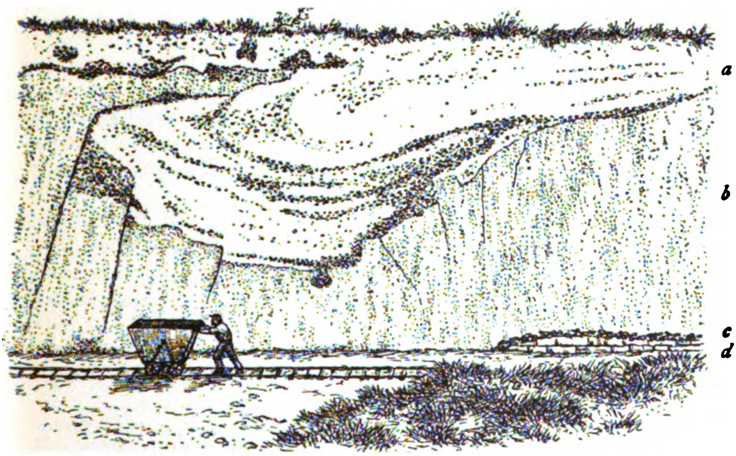

FIG. 4.—SECTION SEEN AT THE TOP OF A CHALK QUARRY AT GRAYS, SHOWING THE SUBSIDENCE OF THE THANET SAND AND RIVER-GRAVEL DUE TO SUBTERRANEAN EROSION OF THE CHALK.

(*a*) River-gravel mixed with loam.
(*b*) Thanet sand.
(*c*) Bed of green-coated flints.
(*d*) Chalk.

in the process, and the hollow was filled up by a mixture of gravel and loam which had been washed in from the top. After noticing another section close by, where the river gravel had been deposited in a pre-existing hollow in the Thanet Sand, the party visited one of the tramway cuttings which lead from the quarries to the river. The finely laminated brick earth and sand deposited against the old chalk cliff was well exposed, and a thin bed of gravel was seen resting upon it. This gravel belongs to the lower terrace of the Thames valley, forming a thick deposit about twenty feet above ordnance datum near the river, and extending upwards here and there in a thinner bed over the more ancient brick earth. Good specimens of palæoliths were found in the brick earth by Mr. A. S. Kennard. Afterwards the party crossed the chalk hill to the north side, along which the gravel of the middle terrace extends. One pit was noticed in passing, but it was much overgrown, and there was not time to visit others which show better sections. It was pointed out that the middle terrace gravel rests on a platform about fifty feet above ordnance datum, and covers a large area on the north side of the Thames. In this neighbourhood it passes to the north of the Grays chalk hill, and no gravel at a corresponding level appears to exist in the present river valley between Purfleet and Grays. Hence it would appear that the Thames flowed in a more northerly channel during its formation, a conclusion first suggested by Mr. T. V. Holmes (*Essex Naturalist*, vol. vii). The main mass of the Thames Valley brick earth (with which that at Grays is approximately contemporaneous) rests on the middle terrace gravel. Hence it is intermediate in age between the gravels of the middle and lower terraces. The Cretaceous and Lower Tertiary strata in this part dip gently to the north, and within a short distance are lost to view under the London clay.

Crossing the bridge over the railway cutting at Purfleet a good view was obtained of a pillar of chalk capped by Thanet Sand, which has been isolated by quarrying operations, and now forms a picturesque feature in the old quarries.

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VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY), CROMWELL ROAD.

MARCH 28TH, 1903.

Director: GEORGE PRIOR, M.A., Assistant, Mineralogical Department.

(*Report by* THE DIRECTOR.)

A large party met at the Natural History Museum for the purpose of inspecting the Mineralogical Galleries. Mr. L. Fletcher, M.A., F.R.S., Keeper of that Department, had kindly promised to act as director, but was unavoidably prevented from being present. Mr. Prior, however, very kindly took his place, and the members, as on many former occasions, spent an interesting afternoon in the Museum.

Mr. Prior, having first pointed out in the Central Hall the meteoric stone, which fell last September, at Crumlin, Co. Antrim, conducted the party to the collection of meteorites in the Mineral Gallery, and gave a short historical account of these interesting objects. By reference to well-authenticated falls of stones, such as those of Siena, Wold Cottage in Yorkshire, and L'Aigle, he showed how the evidence gradually accumulated which led to the final recognition of these objects as genuine visitors to us from outer space. He pointed out various types of meteorites, from the enormous mass, weighing 3½ tons, found at Cranbourne, near Melbourne, which consists mainly of nickeliferous iron, to a fragment of the oldest undoubted meteoric stone still preserved, which fell in 1492 at Ensisheim in Elsass, and consists mainly of stony matter. He finally discussed briefly the connection between these sky-stones and shooting stars or comets. On their way out from the Mineral Gallery the members were shown, amongst other objects of interest, specimens of flexible sandstone, a unique set of magnificent crystals of Topaz, fine examples of Proustite (sulph-arsenite of silver) from Chili, and the large Colenso diamond.

EXCURSION TO SALISBURY AND THE VALE OF WARDOUR.

EASTER (APRIL 9TH—14TH), 1903.

Directors: Dr. H. P. BLACKMORE, M.D., F.G.S., and Rev. W. R. ANDREWS, F.G.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Reported by* the Rev. W. R. ANDREWS and W. P. D. STEBBING with Notes by the PRESIDENT and W. H. HUDLESTON.)

OLD SARUM AND STONEHENGE. April 10th.

(*Reported by* W. P. D. STEBBING.)

Arriving at Salisbury on the Thursday the party put up at the County Hotel, the headquarters during this visit to the district after an absence of 22 years. The first day of this excursion, under the directorship of Dr. Blackmore, was devoted to the district northwards of Salisbury, including Stonehenge and the historic locality of Fisherton.

Leaving the hotel in brakes the party immediately drove to Old Sarum, where a halt was made while the director pointed out the position of the ancient city situated on the end of a chalk spur, the highest part of which is probably in the Marsupite zone, and isolated by extensive trenches and banks. Entering the outer ward by the main entrance and then ascending into the citadel, still retaining remains of its Norman masonry fortifications, the director gave an outline of its history from the time when it was a British hill fort, and pointed out while walking round the bank of this inner mound, the position of the various parts of the medieval town. From this vantage point the director also called attention to the different points of the high ground around, and indicated the zones of the chalk forming them.

Descending towards the Avon the party halted at a chalk pit at the northern foot of Old Sarum and by the side of the road.

The director pointed out that the chalk here belonged to the lower Uintacrinus bed of the Marsupite zone, a fact abundantly proved by specimens found by the party. The rubble chalk above was not, the director said, rain wash, but a result of the extensive defensive work on the slopes of the camp.

That this zone, as at Margate, was almost free from flints

though on the geological map the whole upper chalk is marked as "soft with flints."

Rather lower down and nearer the river another chalk pit by some tumuli, and a little north of the Manor House, was visited. The chalk here had fairly horizontal flint bands throughout from top to bottom of the pit. There was no Uintacrinus as it is in the upper part of the *Micraster cor-anguinum* zone. The director mentioned that *Pecten Britanicus* had been found in this pit. It yielded to the party several fossils and a paramoudra.

Returning to the carriages the way lay across the Avon and up the valley. At Woodford another pit was visited in the *M. cor-anguinum* zone, and also probably the top of the *M. cor-testudinarium* zone, which is brought up towards Amesbury by a slight dip to the south. The chalk in this section was rather hard and nodular and had flints throughout. It was unique in the district in containing a considerable quantity of common salt.

From the hill above this pit a good view was obtained of the valley of the Avon, and of three well-marked terraces on the hill-side to the north of the village. Some discussion was raised as to their origin, the director favouring the view of their formation by the river, or its representatives in Pleistocene times. An interesting feature also pointed out was an isolated hill surrounded by a valley, now dry, containing a deposit of brick-earth, laid down evidently by the river, before its present valley was so deep, with the help of streams from the chalk plateau.

On arriving at Stonehenge the director gave a most interesting account. A date for its erection of about 2,000 B.C. has now been assigned. This fresh view as to its age has been brought about, partly by the recent excavations for raising the leaning stone at the back of the altar stone, during which rude flint implements and sarsen stone mauls of neolithic age were found, and partly through recent astronomical observations and data. The director described the stones, their number and petrology, and started an interesting discussion as to the original home of the small blue stones, a kind of diabase, and as to the locality whence the builders of Stonehenge obtained them. The president reviewed the evidence, and added arguments of his own.

Afterwards some time was spent in and around the stones, fragments of diabase, unearthed by the excavations, being obtained by some of the party, one sanguine member informing us that some day they would be worth their weight in gold. A curiosity in sarsens, one containing pebbles, was also hailed with joy. This happened to be the broken cap stone of the trilithon that fell at the beginning of 1901.

The President (Mr. H. W. Monckton) remarked that the larger stones appeared to be sarsens of a normal kind, and he felt inclined to agree with those who thought that they came from

the Bagshot Beds. Some of them were of a rather exceptional character, thus in one there were layers of flint pebbles and other signs of stratification, and one or two other stones were clearly stratified. Now signs of stratification are not common in sarsens.

As to the blue stones, it appeared to be the opinion of the best authorities that they might have come from the West of England, but there was a considerable difference of opinion as to the way in which they were brought to Stonehenge.

The theories on the subject might be divided into three classes: 1st, that the stones were brought by man from the west of England or from some other distant place; 2nd, that they are boulders from the Glacial Drift which it is assumed once extended over this area (W. Gowland and Prof. J. W. Judd, "Recent Excavations at Stonehenge, *Archæologia*," vol. lviii, p. 81 of Sep. copy); 3rd, that they were brought up the Avon on rafts from an erratic-strewn plain now destroyed by, or sunk beneath the sea lying off the present mouth of the Avon (C. Reid, "Geology of Salisbury," *Mem. Geol. Survey*, 1903, p. 69).

The speaker thought that on the whole the evidence was somewhat in favour of the first of these alternatives. It was objected to it (and the objection applied equally to the third proposition) that the blue stones are proved by excavations to have been chipped to their present size and shape at Stonehenge, and that, had they been brought from any distance, the chipping would have been done before the bearers started. It was, however, possible that the stones had been transported at one time and chipped at a much later time by a different people. The great objection to the second proposition is that so far "no trace of erratics has yet been met with in this area." C. Reid, *op. cit.*, p. 69.

From Stonehenge the party drove into the Devizes road to return to Salisbury. The first stop was at a chalk pit on Camp Down about 450 feet O.D. in the M. cor-anguinum zone. The surface of the ground here has a thin capping of gravel mapped as Plateau gravel, and a small pipe in the chalk was filled with gravel consisting mainly of flint. In the memoir to sheet 298 it is suggested that these isolated patches may be reconstructed Eocene outliers.

Continuing on to Bemerton the higher-level gravels on the new building estate near the cemetery were visited. Some little time was spent in examining these unstratified dark red deposits mapped as valley gravels. The director said that he had obtained a very few Palæolithic implements from the deposit. Patches of red brickearth occurred in the excavations, and abundant sarsen stones, many of a very hard and cherty nature. Rubble chalk, remaining in the form of pinnacles, was seen in several places under the gravel.

The last stop of the day was at Harding's Chalk Pit at

Highfield, Fisherton. This section is in the lower part of the Marsupites zone, and contains Uintacrinus. The chalk here is very soft and pure with few flints, is capped with three to five feet of dark red unstratified gravel, and traversed by long, deep and narrow pipes.

Just below this last section occurs the famous Fisherton brickearth pit, where a few minutes were spent. The deposit is very little worked now, and is rather overgrown, the cream-coloured hand-made bricks hardly paying to make. A complete section, therefore, cannot be made out, but a good many feet of brickearth with a light-coloured fine marl below were available for collecting the abundant mollusca. The deposit is banked up against the chalk and the director explained that the finer beds of the section were probably laid down in a quiet eddy of the river which at one time ran at the foot of the cliff; while the origin of the beds containing the coarser materials might be explained by a talus deposit at the foot of the chalk cliff fed by the subaerial denudation of the surface above.

This section closed the day's excursion, from this point the party driving back to the hotel.

TEFFONT EWYAS AND CHILMARK.

APRIL 11TH.

Director: REV. W. R. ANDREWS, F.G.S.

(*Report by* THE DIRECTOR.)

The members assembled at Salisbury Railway Station at 10 a.m. and took the train to Dinton.

The general outline of the Geology of the Vale of Wardour was briefly pointed out, and with the aid of the excellent new Survey Map (Sheet 298), which was in the hands of most of the party, a good appreciation of the chief features of the district was soon arrived at.

The Vale of Wardour was described as bounded on the north and south by the Chalk Downs, and that within these two ranges of Downs, two other hill-ranges, viz., of "Upper Green Sand," which constitutes one of the most picturesque features of the landscape; that emerging from beneath the escarpments of these sand hills on either side of the Vale, the "Gault and Lower Green Sand" were continuous on both sides, and might be seen in the more gently sloping ground; while in the centre of the Vale, rising from beneath the Lower Cretaceous Series, were the Upper Formation of the Jurassic Beds, viz., the Purbeck, the Portland, and the Kimeridge Clay.

The flexures which these strata have undergone, and the

present geological structure of the Vale were explained as follows: that the various members of the Jurassic System and the Wealden were in this district tilted towards the south-east, previous to the Lower Green Sand being deposited on their upturned edges. Thus there is an unconformity, with overlap, between the Jurassic and the Cretaceous Beds. In the small diagrammatic map, p. 151, a marked black line has been drawn between these two systems, and serves to emphasise the position of this geological break. And in the 1-inch Survey Map the same peculiarity may be observed by noticing the position of the thin band of Lower Green Sand resting successively on each member of the Jurassic Series in a descending order, as we pass from the eastern end of the Vale to the western end. After the deposition of all the Cretaceous Beds, and their elevation to dry land, a very important earth movement commenced, and an anticlinal was formed, which running east and west through the Vale, caused all the strata to dip away from the central line towards the north and south.

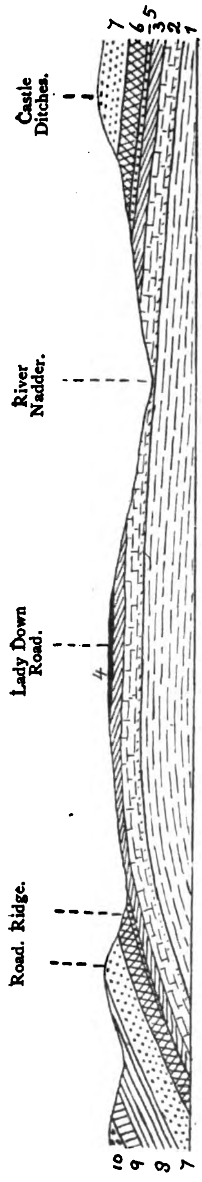

FIG. 5.—SECTION ACROSS THE ANTICLINE OF THE VALE OF WARDOUR.

Hor. Scale, 2 inches to a mile. Vert. Scale, 1,200 feet to an inch.

	Feet.		Feet.
10. Upper Chalk		5. Lower Greensand	30
9. Middle Chalk	100	4. Middle Purbeck	
8. Lower Chalk	200	3. Lower Purbeck	65
7. Upper Greensand	150	2. Portland Beds	120
6. Gault...	90	1. Kimeridge Clay	

It is worth notice that the drainage of the Vale of Wardour is effected by a river which flows out of its eastern end, and that the lateral streams flow into the Vale to join this river, none of them flowing outward through gaps in the Chalk

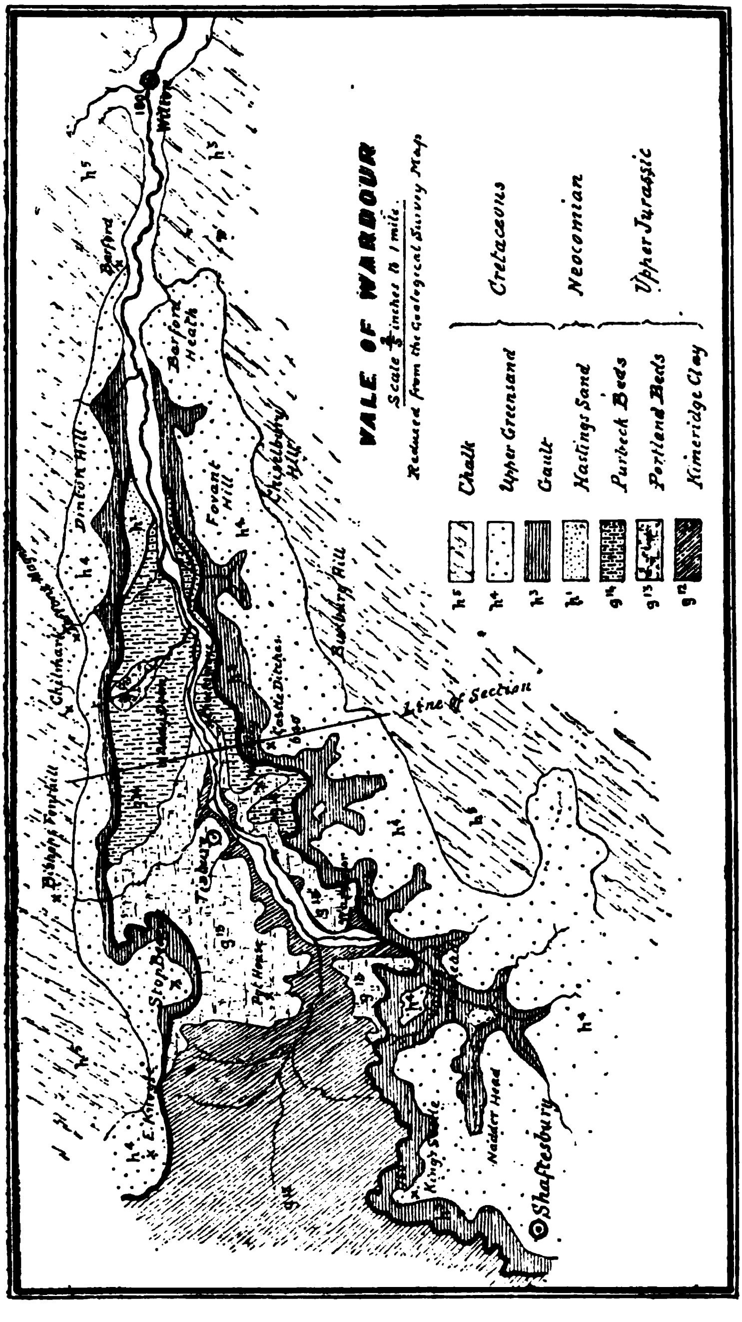
VALE OF WARDOUR
Reduced from the Geological Survey Map
h5 Chalk
h4 Upper Greensand
h3 Gault
h1 Hastings Sand
g14 Purbeck Beds
g13 Portland Beds
g12 Kimeridge Clay
Cretaceous
Neocomian
Upper Jurassic
Line of Section
Wilton
Barford
Barford Heath
Dinton Hill
Fovant Hill
Chiselbury Hill
Buxbury Hill
Castle Ditches
Bishops Fonthill
Tisbury
Stop Beacon
E. Knoyle
Nadder Head
King's Settle
Shaftesbury

FIG. 6.

escarpment as in the cases of the Weald and the Vale of Pewsey. The explanation of the difference is probably that the Wardour anticline was, in the first place, abruptly truncated by the basal plain of the Eocene deposits, and that subsequently, when the existing drainage system was established, the anticline did not become part of the dominant watershed of southern England. The courses of the Avon and the Stour show that these rivers established themselves on a plain which sloped southward across the anticlines of the Vales of Warminster, Wardour, and Broad Chalk, these flexures only influencing the courses of the tributary streams so far as to give them an easterly direction.

The members walked to Teffont Ewyas Lodge, through the Manor House Gardens, by the courtesy of C. E. Maudeslay, Esq., and then by a lane and field path to the Portland Quarries in the Chilmark Valley.

Commencing with the uppermost section on the eastern, or Teffont side of the Chilmark Valley, which shows 17 ft. 7 in. of the Lower Purbecks resting on the Portlands, the dividing line, which here consists of a thin seam of clay, 3 in. to 6 in. thick, was first pointed out, and the reasons given for placing the division at that horizon, viz., that below the band of clay was a thick stratum of buff-coloured oolitic stone, which contains cast of Portlandian fossils, *Cerithium portlandicum*, etc., whilst above the band of clay is a travertine rock with some few casts of fossils, not very distinguishable, but which are recognised as *Cyrena rugosa*.

The junction between the two formations was carefully examined, and the utilisation of the Clay band as a base line for the Purbeck beds met with general approval.

Having fixed on the base of the Purbeck beds, the 17 ft. above the dividing line were next investigated. Beneath the surface soil 3ft. 8in. of thin calcareous bands were pointed out, which present a curved, undulating aspect, and overlie the old land surface, or so-called "Dirt Bed," which proved of great interest. The director indicated the position where a fossil-coniferous tree, four or five feet high, had stood upright in the old earth surface some few years ago, till thrown down and removed to the office of the proprietor near. Especial attention was called to the rare geological phenomenon which they had before them, as it was very seldom that any old earth surface was preserved. Some members climbed up to investigate the bed more closely, and at the base of the hollow, where the tree had stood, found several fragments of fossil wood, which were probably some of the roots of the tree. It was evident that considerable erosion had taken place at this horizon, as the under surface of the bed was water-worn into hollows, and many rolled pebbles from the underlying bed were mixed up with the dark material of the "Dirt Bed." Mr. W. Whitaker selected some

of the darker pebbles, which his experience led him to think might contain phosphates, and which he reserved for analysis.

Tufaceous limestone immediately succeeds, 6ft. thick, then a band of calcareous oolitic grit, 1ft. 6in., containing two bands of flint, the upper of which is oolitic, and then, again, tufaceous limestone 4ft. thick down to the dividing band of clay.

Interesting specimens of the fossil wood, the rolled pebbles, oolitic flint, and botryoidal limestone were reserved by some members for future investigation.

The highest Portland rock, on the Teffont or eastern side of the Chilmark Valley, which has been called the "Upper Building Stone," or "Upper Cyrena Bed," was next described as a fine buff-coloured oolitic stone, 18ft. thick, much valued for carved work, and formerly used largely for the building of Old Sarum Cathedral in the eleventh century. Especial attention was called to this bed of rock, for although it is a thick bed here on the eastern side of the Chilmark Valley, it is but slightly represented on the western side, and is absent in the old quarries of Chicksgrove and of Wockley, unless its equivalent there may be a thin band of fossil stone about one foot thick, and the distance between the two sections is less than two miles.

The junction between the "Upper Building Stone" and the succeeding "Chalky" Series is obscured by rubbish.

Descending to a lower level in the quarries, the "Chalky" Series was next examined, and showed a section of 24 feet of soft white rock, with both horizontal and vertical bands of flint in the upper 14 feet, at first sight looking very like an ordinary Upper Chalk quarry, but Portland fossils were soon found, and it was explained that the white "Chalky" rock consisted of minute particles of calcite, probably derived from the destruction of shells, and that when a thin section is examined under a microscope, it is found to be quite different from chalk—had not a similar origin. At the base of the "Chalky" Series comes in a most interesting band of rock, about 12 feet thick, and divided into three or four beds, the upper of which is a soft rock about 2 feet thick, called the "White Bed," the lower consist of hard shelly limestone, often 10 feet thick, and called the "Rag" stone.

This band of rocks, coming as it does between two thoroughly marine series, and containing a very different fauna, indicates some important physical change, and probably one that caused an alteration of the debouchure of the river or rivers which here drained into the Portlandian Sea.

Mr. W. H. Hudleston, than whom no one is better acquainted with these beds, and whom we were all glad to see, very kindly described them as being of exceptional interest, and containing fossils in an admirable state of preserva-

tion, which he illustrated by means of specimens he had brought with him, showing the contrast between *Cerithium Portlandicum*, which occurs plentifully in the "Upper Building Stone," and *Cerithium Concavum*, which occurs plentifully, often standing out in beautiful relief, in these beds. Other Gasteropoda peculiar to these beds, were shown and admired.

At or about the horizon of these "Rag" beds the celebrated "Star Flint," silicified coral, has been found north-west of Tisbury, but it does not occur in the Chilmark Quarries.

The Chief "Building Stone" or "Freestone," which is largely quarried on both sides of the Chilmark Valley, was next noticed, consisting of about 18 feet of a more or less glauconitic sandy limestone, a very excellent and durable stone, used for many centuries, and of which, from these quarries, the present Salisbury Cathedral was built in the thirteenth century, as well as many other important buildings. Much stone has been extracted from long galleries, extending a considerable distance into the hill side, one of which was explored, and lighted by means of magnesium wire.

Below the base of the "Building Stones" there is no section visible, but the thickness of the "Basement" Beds of the Lower Portlands has been estimated at 38 feet, from a well sinking passing down to the Kimmeridge Clay, and going through chiefly sands and clays.

Although these 38 feet of "Basement" Bed cannot be seen in the Chilmark Vale, Prof. Blake reports in a section on the roadside between Tisbury and Wardour some strata of sand and rubbly calcareous rock containing an interesting fauna, and lying between the base of the Freestones and the Kimmeridge Clay.

The members returned to Teffont by a different route, crossing the Middle Purbecks and Upper Purbecks to the north-east of the Chilmark Valley, they investigated the pebbly base of the thin band of Lower Green Sand, and some of the quartz and Lydianite pebbles were collected. Then ascending the slope across the Gault, had the opportunity of seeing a small section of the Malm Stone which forms the basal part of the Upper Green Sand.

Arriving at the village of Teffont, the Director distributed some specimens of the *Archæoniscus Brodiei*, which he had brought there, it being inconvenient for a large party to visit the best locality for that fossil in a small quarry in a railway cutting west of Dinton.

The section in the Lower and Middle Purbeck Beds on the higher ground west of the church and village of Teffont Ewyas was next visited. A long excavation has been in progress for many years, and the so-called "lias" stone burned for lime. Much of the excavation is now obscured, but one very good complete section from a little below the Archæoniscus Bed down

to the base of the 3rd "Lias" Bed was well seen. The "Cinder" Bed was pointed out, and described as a most valuable horizon from its wide extension and distinctly marine character, coming amongst purely freshwater strata. The fossils occurring in the "Cinder" Bed including *Ostrea distorta*, *Trigonia gibbosa*, *T. densinoda*, *and Hemicidaris purbeckensis*. The various beds below the "Cinder" Bed were each in turn indicated, and their interesting fossils, viz., remains of small crocodiles, turtles, fishes, insects, Estheriæ, Ostracods, and plants.

Alluding to the three-fold division of the Purbeck formation by Prof. Forbes, according to the range of certain species of Cyprides, the base of the Middle Purbecks was considered to be a brown and black shaley clay, about 10 ft. below the "Cinder" Bed, because there *Cypridea fasciculosa*, the characteristic Cyprid of the Middle Purbecks, first made its appearance, although the characteristic Cyprid of the Lower Purbecks, viz, *Cypris purbeckensis*, had not entirely died out.

APRIL 12TH.

On the morning of this day a fair number of the party walked across the downs to the south of Salisbury to visit some exposures of the chalk rock about Coombe Bissett and Homington in the Ebble valley.

In the afternoon the party met at the Blackmore Museum. Dr. Blackmore conducted the party round the building, especially commenting on the fine series of Eolithic and Palæolithic implements. An exhihit that roused a good deal of interest consisted of a series of Palæolithic implements from Knowl Hill in Savernake Forest with polished or varnished looking streaks across them, due probably to silica deposited by running water.

TISBURY, WOCKLEY, LADY DOWN, AND RIDGE.

APRIL 13TH.

Director: REV. W. R. ANDREWS.

(*Report by* THE DIRECTOR.)

THE members went by rail to Tisbury, and walked by field paths to Wockley Quarry, where there is an exposure of about 28 feet of the Lower Purbeck lying on the lower portion (without flints) of the Portland Chalky Series. It was pointed out that at Wockley there was a great difference in the passage from the Portland to the Purbeck Beds, as contrasted with the section at Chilmark only two miles distant; that a considerable thickness of the uppermost Portland Beds were here not represented, viz., 14 feet of the "Chalky-series-with-flints," and 18 feet of the "Upper Building Stone." Two theories were put forward to

account for the absence of these beds—the one that there was an unconformity here, due to the beds having been raised and removed by denudation; the other that there was no unconformity, but a gradual passage from the Portland to the Purbeck Beds, the absence of the 30 feet of Portland Beds being accounted for by the thinning out of the beds in the distance between the two quarries. This latter was considered the more likely by the Director, both from the absence of marked signs of erosion, and from the great variation in the thickness of beds even at moderate distances.

The actual junction was next closely examined, and attention was drawn to the bed, indicated below, 2 feet 3 inches thick, which consists of two parts, a chalky limestone full of the shells of *Pecton lamellosus* in the lower half, firmly welded to a fissile lime-stone containing Cyprides in the upper half. Such a block from this horizon, either at Chicksgrove or Wockley, was deposited in the Museum of Practical Geology many years ago, where it can now be seen, and it is remarkable as showing an abrupt lithological transition, but the palæontological transition is not so marked, for the Cyprides in the upper half of the block, viz., the fissile stone, have been found to be estuarine forms. Hence the passage from the purely marine Portland Beds to the freshwater Purbeck Beds above, is bridged over by a stratum which contains estuarine fossils. This closer view of the junction confirms the broader view as to there being no unconformity here, but a complete passage, and that the difference between the two sections at Chilmark and Wockley may be attributed to causes which locally produced a deposit of the beds in the one case and not in the other.† In the "fissile" stone several specimens of *Ophiopsis* and Cyprides were found.

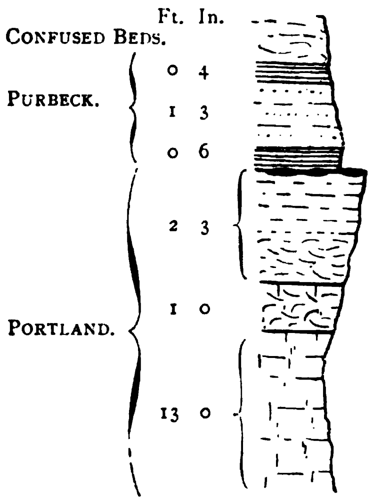

FIG. 7.—SECTION OF QUARRY AT WOCKLEY.*

The overlying Purbecks were next examined. The brown and dark clay, 4 inches, proved to be largely a re-arranged soil, as fragments of exogenous wood were found. The "Confused Beds" reminded those who had seen the coast sections in Dorset

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† See Mr. A. J. Jukes Browne's paper on the Purbeck beds of the Vale of Wardour in the Geological Magazine, June 1903, pp. 252-254.

of the "Broken Beds" of that locality; and it was suggested by Mr. Whitaker, that the cause of the confusion was due to infiltration of surface water, which had removed the calcareous matter, and that consequently the less soluble layer of yellow ferruginous stone above had fallen in and produced the strikingly disturbed condition of this bed.

In higher beds oolitic limestones, crowded with the characteristic Cyprid *Cypris purbeckensis* of the Lower Purbecks was especially noted.

By the kind invitation of Mr. Bracher the party visited Place Farm, as they walked from Wockley quarry to Lady Down, and were much interested in the fine old house, gateway, and ecclesiastical barn, all of which had once belonged to Shaftesbury Abbey.

The quarry on the top of Lady Down showed an excellent section of about 15 feet, chiefly in the Middle Purbecks, extending from the base of the "Lias" Bed, No. 1, up to the horizon of the *Archæoniscus* Bed, some specimens of which were found, thus clearly marking the upper limit. It was pointed out how the thicknesses of the beds here above the "Cinder Bed" differed from what they were near Teffont, as an illustration of the rapid thickening and thinning of these freshwater strata; *e.g.*, a shelly limestone which was almost thinning out near Teffond, here was 3 feet thick, while, on the other hand, the white fissile limestone above, which was 16 inches near Teffont, was here only 4 inches thick. In consequence of such variations it is sometimes difficult to corroborate two quarries a mile or two apart, unless a definite horizon, such as the "*Archæoniscus*" Bed, or the "Cinder" Bed could be identified. From the top of Lady Down, 500 feet, the best general view of the Vale of Wardour, looking westward, was obtained. In the interval between snow storms, the sun came out, the distance was very clear, and a beautiful prospect was obtained. The chalk downs on each side are hidden by the two ranges of Upper Green Sand, rising up to 700 feet, presenting steep escarpments facing each other, and cut back until the extremely hard beds of Chert near the top are reached, and consequently terminating somewhat abruptly. At the base of these Green Sand Hills comes a depression, due to the soft Gault, and then in the centre of the vale at the lower level are the relatively rounded hills of the Purbeck and Portland Beds and Kimeridge Clay.

A visit was next made to a Lower Purbeck Quarry near the hamlet of Ridge, which though somewhat obscured by talus, still showed about 15 feet of limestone with much curious oolitic structure, and in one of the higher beds many angular hollows left by the solution of salt crystals.

The Director here remarked, that now they had seen, by putting together the various small sections, a fairly continuous sequence from the base of the Purbecks up to the top of the

Middle Purbecks, amounting to between 80 and 90 feet, but that, unfortunately, it was not possible for them to see the Upper Purbecks, as this division, consisting chiefly of marls, clay, and sands, and containing no useful beds of stone, was seldom exposed; and that the section in the first railway cutting west of Dinton Station was now completely grassed over and hidden.

A pleasant walk was continued to the hamlet of Ridge, where narrow lanes climb the Upper Green Sand escarpment, and in their banks were seen small sections of buff-coloured sands, with, at one horizon, a thick persistent layer of the shells of *Exogyra conica* and *Ostrea vesiculosa*. A white porous siliceous limestone, of small specific gravity, "Sponge Rock," was noted at the top of the escarpment, and at Knap Farm, just above the Gault pit, a small section of Malmstone was examined.

The Gault pit below was much obscured; still, it was possible to see that here the dark grey micaceous clay was very thick—about 40 ft.—and that it was traversed about 20 ft. from the top by a layer of brown and grey sandy rock.

It was pointed out that the clay pit was in the zone of *Ammonites interruptus*, while the Malmstone and buff-coloured sands, forming the escarpment above, were in the Zone of *Ammonites eostratus*, but the glauconitic sands and Chert Beds, which form the Zone of *Pecten asper*, are not well exposed near Ridge.

After dinner the President proposed a vote of thanks to Mr. Andrews, saying that they had been most fortunate to have as their Director one who was so intimately acquainted with the Vale of Wardour and its geology.

ALDERBURY.

Director: Dr. H. P. BLACKMORE.

APRIL 14TH.

(*Reported by* THE DIRECTOR.)

This day's excursion was devoted to the geology of the district to the south-east of Salisbury. Leaving the hotel the party walked through the town and then by the Southampton Road to the first section visited, a chalk pit in the *Bel. mucronata* zone at Shute End.

Pipes in this pit were filled with Reading Beds, and with a coating of greenish loamy sand from the hill to the east.

The Reading Beds above the river here are in a state of rather unstable equilibrium, the director related an instance of a man

building a house on the slope, and then, through the insufficiency in depth of the foundations and its weight, found it slowly slipping down the hill.

A short distance up the hill on the main road the party visited a shallow gravel pit, showing sandy gravel, stiff blue clay, and masses of iron-hardened sand, identified by the director as Bagshot Beds, but he would not commit himself to what division of that formation it belongs. The new geological map also does not commit itself.

Continuing on, a very fine section in Plateau gravel, level 320 ft. O.D., at the back of the Alderbury Post Office, was entered. The director, in describing the section, said that the gravel did not slope towards the river, and was perhaps part of the ancient Solent River system. The materials composing the gravel were flints of all sizes, some comparatively little rolled, tertiary pebbles and greensand. Beds of sand occur towards the lower part of the section, and along part of one side of the pit was seen a peculiar layer of white clay containing no lime, as one would rather have expected from its colour. The director said that many Eolithic flint implements had been found here, and spent some time adjudicating on the many artificially or otherwise shaped pieces of flint brought up to him.

The following note on this gravel is by Mr. H. W. Monckton:

The section (at Ivy Church) shows some 18 feet of gravel, roughly but distinctly stratified. There is a little loamy clay in places, probably derived from the Bagshot beds, but on the whole the material is coarse. The gravel is very ferruginous, and in places it is cemented into a hard conglomerate.

The gravel consists of: (1) black sub-angular fragments of flint from the chalk; (2) brown sub-angular flints, probably from older gravels; (3) flint pebbles from the Eocene pebble beds; (4) Sarsens, probably from the Bagshot beds; (5) fragments and pebbles from the Upper Greensand; (6) blocks of ferruginous sandstone from the Bagshot beds.

This gravel is almost certainly a river gravel, and the abundance of Upper Greensand fragments seems to suggest a river flowing from the direction of the Vale of Wardour, an early edition of the River Nadder in fact. This was pointed out by Mr. Whitaker during our visit to the pit.

This gravel caps a hill, rests on the Bagshot beds, and looking at its situation I feel little doubt that the many bits of sarsen in it came from that formation rather than from the Reading beds, and this evidence serves to strengthen my opinion that the sarsens of Stonehenge are from the Bagshot beds too.

I could find nothing like the blue stones of Stonehenge in the gravel here, or in any of the gravels around Salisbury, and I feel the greatest doubt whether they can have been derived from drift of this neighbourhood. Not only do they appear to be absent

from the gravels, but none seem to have been found as gateposts or corner stones anywhere about the district.

A path to the north thence took the party to the famous Clarendon railway cutting in the London Clay—where the late F. E. Edwards obtained a large number of new species, many of them still unnamed, now to be seen in the collection called after his name at the Natural History Museum.

The section is very much grown over now, but with the short time allowed for collecting a good many small specimens of typical species were found.

From this point a large brickfield in the London Clay was visited; it is unfossiliferous except for sharks' teeth, which we were told are carefully removed by the men, as they are liable to cut their hands severely when brick making.

Passing into the Clarendon Park Woods, some time was spent, partly for rest and refreshment, in a chalk pit in the *Bel. mucronata* zone. During the stop here the President proposed a hearty vote of thanks to the director, to which he replied. Leaving this spot, a short stay was made by the side of a field in order to inspect a Sarsen, about 6 ft. long, well sand-polished in places, before visiting the scanty remains, now in a wood, of the old palace of Clarendon, where the famous statutes of that name were drawn up and signed in the reign of Henry II.

Everything must have an end, and so, our day's arrangements being officially finished here, from this point broke up the Easter excursion of 1903.

NOTE.

The chalk zones are best observed in the following quarries:

Shute End, Alderbury, Clarendon Wood	*Belemnitella mucronata*-zone.
Britford, East and West Hainham	*Actinocamax quadrata*-zone.
Bishop Down, Ford Hill	*Marsupites*-zone.
Devizes Road (Harding's Pit), Old Sarum	*Uintacrinus*-zone.
Stratford, Quidhampton	*Micraster coranguinum*-zone.
Hornington, Coombe Bissett	Chalk Rock.

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EXCURSION TO THE LOAMPIT, LEWISHAM, CROFTON PARK, AND THE HORNIMAN MUSEUM.

APRIL 25TH, 1903.

Directors: W. WHITAKER, B.A., F.R.S., AND A. E. SALTER, B.Sc., F.G.S.

(*Report by* MR. SALTER.)

A LARGE party assembled at St. John's Station, S.E. & C.R., at 2.30 p.m. From the end of the platform the faulted junction of the Thanet Sands against the Upper Chalk was pointed out. By means of well sections, etc., further east, it has been ascertained that the maximum amount of difference of level between the disturbed strata is about 100 feet.

Some large blocks which had been obtained in digging a deep sewer at Malpas Road were shown. They were full of shells, chiefly *Cyrena cordata* and *Cyrena cuneiformis.*

On reaching the old loampit, a section was seen showing unevenly denuded Thanet Sand covered by Drift gravel, and in some places with a little of the Woolwich Beds left between.

The contents of this gravel point to its southern derivation, and it is probably connected with the old Ravensbourne.

Proceeding to Algernon Road, the section in Messrs. Jerrard's stone-yard was examined. Here the Woolwich Beds rest on the Thanet Sand. The shell beds are well developed, and consist of

an oyster bed with beds containing Cyrena above and below. A well-marked pebble bed also occurs.

From the oyster bed Mr. Bassett was fortunate enough to obtain a portion of the plastron of a turtle which Mr. E. T. Newton, F.R.S., has referred to Trionyx?

In the brickfields near the Hilly Fields recreation ground the basement bed of the London Clay is well shown. A small species of Ditrupa was found to occur in it. Below, the sandy beds, with lenticular clay partings, belonging to the Woolwich Beds, were well exposed.

From the top of the Hilly Fields, 156.4 feet O.D., the nature of the surrounding country was pointed out, and the great extent which the country had been moulded by denudation noted. On a clear day the North Downs are plainly visible.

In a small pit on the south side of the hill the London Clay was again exposed. Septaria and Selenite crystals were fairly abundant, and owing to recent slipping some good examples of slickensides were on view.

On the lower ground, near Crofton Park, the Woolwich Beds were again seen. They are bent into a slight anticlinal, and are very similar in character to the beds seen in the cutting on the L.B. & S.C.R., near New Cross, on April 18th. In both the Paludina Bed is exposed. At New Cross it is very fossiliferous, and yields abundant Paludina, Unio, and a few *Pitharella Rickmanni*, but in the cutting now examined the clayey limestone band yielded a few Paludina only.

The final section visited showed London Clay resting on sands, with a few clayey patches somewhat similar to the beds found in the brickyard in the Loampit section.

At the Horniman Museum, after tea, the members examined various exhibits under the direction of the curator, Mr. Quick, and Mr. J. W. Garnham, M.J.S. The latter described his loan collection of carved Jade and Quartz, which were all much admired.

His remarks on Jade were as follows:—

Jade is principally found in China, Siberia, New Zealand, and Islands in the South Pacific.

True Jade is a native Silicate of Calcium and Magnesia.

Nowhere is Jade found so extensively and prized so highly as in China. A good deal of so-called Jade is really Jadeite, which is a silicate of Alumina and Sodium; Jadeite is brighter colour and harder than Jade. It is found in Burmah, and is doubtless the substance of which many of the old Mexican and Central American ornaments were made. An Egyptian Scarabaeus in Jadeite has been found, and axes of Jadeite have been discovered in the Lake dwellings of Central Europe, although the mineral itself is unknown in Europe.

In China, Jade is most ingeniously and elaborately carved. It is called Yu-chi or yu-stone, and has for ages been obtained from the Kuen-lun Mountains, where it is found in veins among the schistose and gneissose rocks.

Jade from this district has been known to the Chinese for over two thousand years. Confucius regarded it as the emblem of all virtues.

Very fine dark green Jade is found in Siberia in boulders. There is a fine specimen in the Natural History Museum. The mines of Chinese Turkestan are, so far as is known, the only mines which are regularly worked. There are over one hundred of them riddling one large mountain side with dark tunnels giving access to long galleries winding in all directions; in some cases going right through to the other side of the mountain. It is found in veins several feet thick, but so full of fissures that perfect blocks are not often found of more than a few inches thick. It is for this reason that large pieces are so valuable, and are usually reserved for the imperial tribute.

At Canton there is a great Jade market. Ornaments, which are mostly bracelets, hair pins, beads, etc., are on sale, and these are as dear to Chinese ladies as diamonds are to us.

The stone is very difficult to work, and hence the great cost of carved specimens. Jade is worked in India into ornaments, sword handles, etc., and often rubies and precious stones are set in them.

Votes of thanks for their kindness were given to Mr. Quick and Mr. Garnham, and Mr. Salter stated that he wished to acknowledge the great help he had received in arranging this excursion from Mr. A. C. Young, F.C.S., whose enforced absence that afternoon he much regretted.

ORDINARY MEETING.

FRIDAY, APRIL 3RD, 1903.

H. W. MONCKTON, F.L.S., F.G.S., President, in the Chair.

The following were elected members of the Association:— F. P. Clark, B.A., LL.B., Rev. S. J. Ford, Hugh C. Montgomery, B. C. Polkinghorne, B.Sc.

A paper by Dr. Wheelton Hind on "The Geology of North Staffordshire," with special reference to the Whitsuntide excursion, was then read by Mr. J. Allen Howe, after which Mr. Walcot Gibson gave an interesting account of the Coal Measures of North Staffordshire.

ORDINARY MEETING.

FRIDAY, MAY 1ST, 1903.

H. W. MONCKTON, F.L.S., F.G.S., President, in the Chair.

The following were elected members of the Association:—Henry D. Gardner, Jr., Mrs. Kate M. Park, Charles H. Rudge, A.M.I.C.E.

The following paper was then read:—"The Zones of the White Chalk of the English Coast. IV.—Yorkshire." By Dr. A. W. Rowe, F.G.S. The paper was illustrated by lantern slides, and by a fine model of the district on the scale of 6in. to the mile made by Mr. Sherborn. It was announced that the model would be presented to the Municipal Museum at Hull.

EXCURSION TO KEW GARDENS.

MAY 2ND, 1903.

Directors: PROF. J. W. JUDD, C.B., F.R.S., and C. B. CLARKE, F.R.S.

(*Report by* C. B. CLARKE.)

THE Association met at 3.30 p.m. at the principal entrance to the Kew Gardens, and proceeded at once to Museum No. 3, where they saw the type specimens of *Bennettites*, and *Pitys Withaim* and other fossils. In the unavoidable absence of Dr. Dukinfield Scott, the significance of the details of these fossils was explained by Mr. Worsdell. Afterwards, Prof. Judd narrated how that the first thin sections of fossils were executed for Mr. Witham by "Prism" Nicols; and how from this starting point palæobotany and petrology have grown to their present magnitude. The Association moved on to Museum No. 2, where very large and beautiful thin sections of fossils were elucidated by Mr. Worsdell.

On leaving Museum No. 2 the Association was divided into five parties, conducted separately by the two directors, Mr. Worsdell, J. C. Baker, F.R.S., and Dr. O. Stapf. As of special geologic interest, their attention was directed to the only Nipa palm now living in Europe, to the Ginko, to the Tree-ferns, Araucarias, Screw-pines, but in particular to the surprisingly fine collection of Cycads, of which order three or four plants were in bloom.

The members were subsequently entertained at tea by Prof. and Mrs. Judd, and the President expressed the thanks of the Association to the Directors and to the other gentlemen who had so kindly conducted the parties round the gardens, and to Mrs. Judd for her most kind hospitality.

EXCURSION TO CRAYFORD AND ERITH.

MAY 9TH, 1903.

Directors: W. WHITAKER, F.R.S., and A. E. SALTER, B.Sc., F.G.S.

(*Report by* MR. SALTER.)

THE party arrived at Crayford at 2.27 p.m., and at once proceeded to view the sections exposed on the south side of the railway near Wansunt Farm.

The chalk and Thanet sand were well seen in some old pits, but the chief feature observed was the extensive and thick sheet of gravel, etc., now being worked on the edge of Dartford Heath. Here a clear section 54ft. deep was exposed, showing two beds of gravel with false bedded sands and gravel lying between them.

It was pointed out that the constituents of this gravel were mainly flint in various forms, derived from Cretaceous and Tertiary beds or older drift deposits.

Lower Greensand chert was present, and also many quartzites, etc., derived from older drifts on the north side of the Thames Valley.

In many respects the composition of the gravel is similar to that found at Coombe Warren, near Kingston Hill and Wimbledon Common, at about 180ft. O.D. The means whereby such an accumulation of gravel had taken place in the lower part of the Thames Basin at a height which is well above the 100 feet contour line led to an interesting discussion, in which Mr. Salter stated that he was of the opinion that it might have been brought about by an accentuation of the syncline of the London Basin in this district, caused by earth movements acting along old lines of flexure.

Neither here nor at Coombe Warren have Palæolithic implements been recorded, but Mr. F. G. Spurrell has obtained rolled specimens of Gryphæa from the same sheet of gravel.

After passing through Crayford, the old pit from which so many remains of extinct mammalia, Pleistocene shells and Palæolithic implements had been obtained, was pointed out, and the manner in which the Pleistocene deposits are banked against a cliff of chalk shown.

To the right of the road to Erith an interesting pit in brick-earth was examined, in which the top four or five feet showed some curious contortions which had excited much interest when the Belgian geologists visited this district some years ago.

These have been ascribed to ice action, but Mr. Salter pointed out that, since the much higher and very probably much older gravels seen earlier in the afternoon contained

débris from drift beds on the north side of the Thames Valley, this was open to question, and suggested that the phenomena were brought about by conditions which led to the formation of an incipient sludge stream at this point. In some of the contortions the upper surface gravel, etc., were included.

Another pit on the left of the road was visited, and the banking up of the brick-earth against the chalk and Thanet sand plainly seen.

The President proposed a vote of thanks to the directors, and tea at the Wheatley Hotel brought an interesting excursion to a close.

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See also "Record of Excursions," p. 17.

EXCURSION TO ROYSTON, HERTFORDSHIRE.

MAY 16TH, 1903.

Director: HORACE B. WOODWARD, F.R.S., F.G.S.

Excursion Secretary: H. KIDNER.

(*Report by* THE DIRECTOR.)

The members started from King's Cross by the 11.10 a.m. train, reaching Royston at 12.30, and driving thence to Barley. On the way the large chalk-pit south-east of Royston was visited. The Chalk here is wedge-bedded; it contains a few flint layers, clayey seams, and occasional rusty galls due to decomposed iron-pyrites. Several small faults occur here and there, with slickensided surfaces on the planes of movement. The pit is situated on the 300 ft. contour, and the following fossils collected by members, as well as the species subsequently mentioned, were identified by Mr. E. T. Newton, F.R.S.:

Ammonites [Pachydiscus] peramplus, Mant.
Scaphites Geinitzi, d'Orb.
Solariella (Turbo) gemmatus, Sow.
Rhynchonella reedensis, Eth.
Echinocorys scutatus, Leske.
Cidaris sp. (plate).
Micraster cor-bovis, Forbes.
Ventriculites decurrens, T. Smith.

The strata exposed are evidently on the confines of Middle and Upper Chalk. The fossils that have been obtained indicate the zone of *Holaster planus*. A tunnel had been driven into the chalk in one place, as the rock there yielded the best lime.

Along the road to Barley it was noticed that the smooth outlines of the Middle Chalk formed the dominant features, and that there was a local absence of Boulder-Clay. Attention was called to the narrowing of the valley where the road crossed Wardington Bottom, so that there was a broad amphitheatre-like hollow and a view of the disturbed crest of the Upper Chalk to the south.

North of Barley, a small and abandoned chalk-pit (now a dust-bin) was visited. Here the Chalk presented a rubbly, weathered appearance, with bands of harder chalk and occasional green-coated nodules, evidently Chalk Rock. In this pit, which is situated at an elevation of 300 ft., the following fossils were collected:

Inoceramus sp.
Terebratula semiglobosa, Sow.
Micraster Leskei (?), Desm.
Coscinopora (fragment).

The party was now driven through the picturesque village of Barley, under the old sign of the "Fox and Hounds," which stretches across the road, to the "Waggon and Horses," where a brief halt was made; thence the journey was continued to Pinner's Cross, just beyond Smith's End, where the first pit in disturbed chalk was seen.

The Director remarked that a "line of flexure" was marked on the Geological Survey map (Sheet 47), as extending from Therfield (or Tharfield), in Hertfordshire, to near Heydon, in Cambridgeshire, a distance of rather more than 6 miles. There were five localities where evidences of the disturbance had been observed by Mr. W. H. Penning, who was engaged in the Survey.*

The more easterly pit, between Heydon and Great Chishall, was now much overgrown, the Chalk was shattered and there was no recognisable dip. Time did not permit of a visit to it. In the pit at Pinner's Cross, opened to a depth of 12 to 15 feet, two bands of flint were seen to be highly tilted, with a northerly dip

* See Geology of the N.W. part of Essex and the N.E. part of Herts, *Mem. Geol. Survey*, by W. Whitaker, W. H. Penning, and others, 1878, pp. 7 to 11.

of about 45°, and above them (to the north) the Chalk was much disturbed, the tabular and nodular flint-layers were broken and streaked out and a mass of Boulder-clay was banked up against the beds. In this pit (elevation about 400 ft.) *Micraster præcursor*, Rowe, and *Terebratula semiglobosa*, Sow., were obtained.

Other fossils recorded from this pit by the Geological Survey and recently re-examined, are *Inoceramus*, *Rhynchonella reedensis*, Eth, *R. plicatilis*, Sow, *Ventriculites impressus*, T. Smith, and *V. mammillaris*, T. Smith.

From this pit the party was driven to the Lime-pits, south-west of Newsell's Park, and north of Barkway (elevation 440 ft.). Here a large chalk-pit, which has been worked until recently, showed at the western side a face of Chalk about 30 feet in height. Towards the southern end a mass three or four feet thick of chalky Boulder-clay, with glaciated chalk, phosphates from the "Cambridge Greensand," and pieces of Lower Greensand, &c., was to be seen beneath the Chalk. The Chalk throughout was greatly disturbed. Flints were scattered, and chips of fractured flint were dispersed through much of the Chalk. Towards the central portion of the face of Chalk, near the base of the pit, the rock contained much brown sandy earth, and there was a distinct shear-plane, indicating overthrust of a mass from the north. Boulder-clay was elsewhere seen along the northern part of the pit, and it crowned the higher ground to the south. A photograph taken by Mr. Teall brought out indications of differential movements in the Chalk that were not distinctly seen on the ground.* *Holaster planus*, Mant., was the only Chalk fossil obtained from this pit.

The Director pointed out that the main features of the district were marked out before the Glacial period, but that in parts of East Anglia the Chalk was so greatly planed down as to present none of the bold scarps which characterise the Royston Downs and the Chiltern Hills. The higher portions of these hills do not appear to have been glaciated. The ice was arrested, although it extended along the lower slopes towards Watford. In the area near Royston the ice impinged against the scarps of Upper Chalk and bent the strata into an anticline, such as was seen in the pit next to be visited; while in the present instance the Chalk had been crushed and broken, and a tongue of débris-laden ice must have been thrust beneath the overlying mass of shattered Chalk. In the pit previously visited the northern portion of the anticline was seen. These high northerly dips, as marked on the Geological Survey map, were quite local, and could not be connected with the general structure of the area, which presented a normal sequence from the low grounds north of Royston, where the Lower Chalk was exposed, through the

* An account of these disturbances, with illustrations, was brought before the Geological Society by H. B. Woodward, *Quart. Journ. Geol. Soc.*, vol. lix, p. 362.

Middle Chalk and Upper Chalk which formed the Royston Downs, to the higher scarps on the south.

Suggestions were made that the Boulder-clay seen below the Chalk at Barkway, had been introduced through a pipe in the Chalk, or through a dene-hole. But neither explanation could be entertained. None of the features that accompany pipes in the Chalk were present, and there were no indications of clay-with-flints. Moreover, the Boulder-clay was to a certain extent welded to the Chalk above it. This would not have been the case with either a pipe or a dene-hole. Nor is it likely that a dene-hole would have been constructed in shattered chalk in the margin of the scarp. The evidence of the highly tilted Chalk in the pit at Pinner's Cross, of the disturbed Chalk with underlying Boulder-clay at Barkway, and of the bent Chalk north of Reed, taken together formed in the opinion of the Director incontestable evidence of ice-action.

On the way to Reed a halt was made on the high ground, whence a view was obtained to the south along the dip-slope of the Chalk towards the London Basin, and to the north over the successive outcrops of the Chalk to the Gault vale beyond.

The hilly ground of Chalk to the north, much of it bare of drift, afforded a great gathering ground for water, which passed underground with a natural flow towards the south, along the dip. Copious overflow springs occurred at the base of the Totternhoe stone bordering the Chalk Marl on the north, and no doubt great quantities of water could be derived from the area by means of wells. Water travelled but slowly, and in deep wells to the south beneath a thick cover of London Clay it was seldom obtained in great quantity, the supply not being replaced so rapidly as it could be pumped.

The famous springs at Grays, in Essex, probably derive water from that which falls on the borders of Cambridgeshire, Hertfordshire and Essex; but pumping at Grays had been so heavy that Thames water was drawn into the wells.

Other overflow springs from the situated Chalk occur where the Lower Eocene strata form a protecting cover on the dip-slope as near Bishop's Stortford: the underground plane of saturation or "water-table" falling gently towards the north and south from the higher grounds of the Chalk.

Owing to rain a somewhat hurried visit was paid to the last pit, that to the north of Reed, and east of the high road, where evidence of a gentle anticline was seen. There were slight indications of irregularity towards the middle of this pit where scattered flints were noticed, and a part of the Chalk appeared to be brecciated. Boulder-clay occurred on the northern slopes. There was, however, no feature observable in this pit which might not have been attributed to the effects of underground disturbance; but taken in connection with the other evidence the

Director did not doubt that here also the effects were produced by ice-action. The elevation here is 500 feet.

Micraster cor-testudinarium, Goldf., was obtained from this pit.

Other fossils previously collected by the Geological Survey and recently re-examined by Mr. Newton, were *Spondylus spinosus*, Sow.; *Rhynchonella reedensis*, Eth.; *Terebratula semi-globosa*, Sow.; *Cidaris* (spine); *Holaster planus*, Mant.; and *Micraster præcursor*, Rowe.

The party was now driven along the main road (the Ermine Street) to the Bull Inn, at Royston, where tea was provided.

Several members subsequently visited the so-called "cave," situated beneath the Market House. This is a chamber of bee-hive shape, discovered in 1742 and of considerable antiquity. The walls are ornamented by a series of carvings which may belong to the latter part of the 12th century, but it is probable that the chamber was excavated as a place of refuge at a much earlier date.

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CYCLING EXCURSION TO THE DUNSTABLE DOWNS.

MAY 23RD, 1903.

Director: JOHN HOPKINSON, F.L.S., F.G.S., Assoc. Inst. C.E.

Excursion Secretary: HENRY BASSETT, JUN., B.SC., A.I.E.

(*Report by* THE DIRECTOR).

Assembling at Tring Station at 3 o'clock, the party, which included several members of the Hertfordshire Natural History Society, proceeded to the picturesque village of Aldbury, which is situated in a pretty valley cut out of the Chalk, after its escarpment commences, by a stream no longer flowing. The old timbered houses, and the stocks and whipping-post still standing by the side of the village pond, attracted attention; and it was noticed that the hill on the right, where the escarpment commences, is much steeper and rather higher than that on the left, beyond which it ends. The Chalk Rock has been cut through, cropping out near the middle of Moneybury hillside on the right and re-appearing near the top of Aldbury Owers on the left.

Beyond Aldbury the road rises considerably, leaving the valley to cross a spur of Pitstone Hill where it passes over the lower portion of the escarpment, the run down to the plain beyond being very steep. Approaching Ivinghoe a view of the church invited a closer inspection, and most of the party deviated from

the direct route in order to visit it, others examining a pit in the Lower Chalk in which they waited for the archæologically-diverted members.

Ivinghoe Beacon was then ascended. The summit is nearly 800 feet above sea-level, and 200 feet above the road (the Icknield way) where the bicycles were left. The view from it is very fine, and to-day it was unusually clear. When all had assembled the Director gave an explanation of its geological features. It embraced, he said, the whole of the Cretaceous rocks present on the northern margin of the London Basin, except the higher beds of the Upper Chalk. They were standing on, or just above the Melbourne Rock which forms the base of the Middle Chalk. On the summit of the hills behind them were the lower beds of the Upper Chalk, and for some miles along the Dunstable Downs, as far as the Five Knolls, four of which were distinctly visible, the Chalk Rock could be traced a little below the highest ground, its presence being indicated just beyond the upward termination of the steep face of the escarpment, nearly on level ground, by a slight ridge due to its hardness. Beyond the Five Knolls would be seen Totternhoe Castle Hill, the Melbourne Rock forming its summit. Just round the extreme point of the hill were the Totternhoe quarries where the Lower Chalk is now quarried for lime-burning, but the Totternhoe Stone at the base of the hill, for which the quarries were originally opened, is not now quarried as a building-stone. The position of the Melbourne Rock between Totternhoe Knoll and Ivinghoe Beacon could not easily be traced, as it forms no distinct feature in the landscape, but there was no difficulty in determining where the Totternhoe Stone occurred, for each little valley or coombe seen at frequent intervals all along the foot of the downs ended at its base, these valleys in some cases but not in all originating in a spring, owing to the water percolating through the Totternhoe Stone, and being thrown out by the comparatively impervious Chalk Marl below it. This, he said, extended for some distance from the base of the escarpment, its surface being almost horizontal, and its dip where it is exposed being less than when it passes under the great mass of the Chalk.

Pointing out Eddlesborough Church on an isolated hill, the Director said that that hill was an outlier of the Totternhoe Stone on the Chalk Marl. The next village beyond was Eaton Bray, where a thin band of the Upper Greensand appeared, and at a little greater distance in the same direction Billington Hill with its church could be seen, that being on an outlier of the Lower Chalk over the Gault of which the greater part of the plain below them consisted. Beyond this again the picturesque and well-wooded ridge of the Lower Greensand formed the horizon on the north from Leighton Buzzard for some distance across Bedfordshire towards Sandy and Potton. On the left, to the south-east,

the Tring reservoirs which supply the Grand Junction Canal were seen, the farthest being on the Gault, and the other three on the Chalk Marl.

A reference to Mr. Whitaker's paper on Sub-aërial Denudation was then made, and his arguments in favour of the Chalk escarpment being the result of such denudation and not a sea cliff were adduced. A view of an isolated terraced hill between the Downs and Eddlesborough, rising in a shallow valley which was traced up to a deep coombe, afforded an opportunity to broach a theory that some lynchets, at least, as these terraces are called, may be the remains of one side of a coombe, the terraces on each being remarkably similar.

On descending the hill a coombe just below it was examined, and its remarkably flat bottom, and regular, clear-cut side-terraces, were commented upon, a halt being made a little farther on to examine another, the bottom and sides of which are curved. Just beyond the point where the Icknield Way crosses the road from Hemel Hempstead to Leighton Buzzard, a closer inspection of one of these little valleys was made, but this was a true river-valley and not a dry coombe owing its origin to a time when the water-level in the Chalk was higher than it is now. At its head is a spring rising from beneath the Totternhoe Stone, and along its course other springs arise, for it flows nearly parallel with the strike of the rocks at the base of the Totternhoe Stone. Its sides are steep at first, then much less so, the ridge thus formed being believed to indicate the summit of the Totternhoe Stone, above which the Chalk, being softer, has a more gentle slope.

It was here decided not to go on to Well Head, two miles further on the Icknield Way, where similar phenomena occur on a larger scale, and the return journey was commenced, the Hempstead road being taken as far as Dagnall. The road continues through the "Dagnall gap," as this break in the continuity of the downs may be termed, and meets the head of the river Gade by the side of which it then runs. It was left at Dagnall, and soon a long ascent commenced to Ringsall, where there is a small outlier of the Reading Beds, one of those farthest removed from the main mass.

On arriving at Little Gaddesden tea was provided at the Bridgwater Arms, all who started from Tring Station, fifteen in number, partaking of it. On the proposition of the Rev. J. F. Blake a vote of thanks was passed to the Director, and then the return journey was continued through Ashridge Park and over Berkhamsted Common, where the gorse was in full bloom, to Berkhamsted Station. Here one member of the Association was left to return by train, the others cycling on with the Director and Mrs. Hopkinson to their home near Watford, and leaving there after dark for London and elsewhere, one by train the others cycling.

The weather was perfect, and the route as pretty a one as could well be taken within easy distance of London.

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WHITSUNTIDE EXCURSION TO NORTH STAFFORDSHIRE.

MAY 30TH TO JUNE 3RD, 1903.

Directors: WHEELTON HIND, M.D., F.R.C.S., F.G.S., W. GIBSON, B.SC., F.G.S., C. B. WEDD, B.A., F.G.S., and R. FANE DE SALIS, F.G.S.

Excursion Secretary: E. P. RIDLEY.

(*Report by* DR. HIND, MR. GIBSON, and MR. WEDD.)

The object of the excursion was to examine the Carboniferous sequence as exposed in North Staffordshire. Incidentally the fine Bunter pebble quarries at Trentham and the drift at various localities were examined.

The Carboniferous Series may be expressed in the following tabular form representing the sequence from above downwards.

UPPER COAL MEASURES.	*Keele Series.*—Red sandstone, red marl, thin limestones, and coal seams.
	Newcastle-under-Lyme Series.—Grey sandstones, marls, thin coal seams, and thin limestones, two of which at the base.
	Etruria Marl Series.—Red marls, green grits, thin coal seams, and thin limestones.
	Black Band Series.—Grey shales, marls, sandstones, thin coal seams, Black-band ironstones, and thin limestones, with the Bassey Mine ironstone and coal at the base.

True Coal Measures. { Sandstones, marls, shales, coals and ironstones, millstone grits.

Pendleside Series. } Crowstones, shales, and thin black limestones,

Carboniferous Limestone.

Nowhere has any unconformity been noticed, but it is probable that the Pendleside series were not deposited on a level floor, and therefore the sequence between the massive white limestone and the Pendleside series is not always identical at different places.

A marked change in the Carboniferous fauna is noted at the junction of the Carboniferous Limestone and the Pendleside series, the large majority of species found in the limestone not passing upwards, while a totally distinct fauna appears in the Pendleside series and marine beds at various horizons in the Millstone grits and coal measures. A fauna characterised by *Pterino-pecten papyraceus*, *Posidoniella lævis*, and several Cephalopoda, amongst which are *Glyphioceras reticulatus*, *G. diadema*, *G. bilingue*, *G. spirale*, *Dimorphoceras Gilbertsoni*, *D. Loonyi.*

No Life Zones have been made out for the Carboniferous Limestone either in Derbyshire, where it exists as one practically undivided mass, or further north, where intercalations of beds of shale and sandstone produce the Yoredale phase. The Yoredale series of Wensleydale and the north being the Homotaxial equivalent of the upper part of the Carboniferous Limestone of the Midlands, the whole series is characterised by the presence of *Productus giganteus*, *Chonetes papillionaceæ.*

The Pendleside series is a thickening of the shales of the lower part of the Millstone grit series, in which are developed some hard, black, thin, radiolarian limestones.

The series is very local, and does not appear to extend further north than Settle or further south than the Charnwood district, where it is represented by a very small thickness of strata. This series and the Millstone grits are quite absent in South Staffordshire, and are only represented by a few feet of sandstones and shales at Lilleshall, Shropshire, where the limestone itself, from 2,000 to 3,000 feet thick in North Staffordshire, thins away to 150 feet.

The Pendleside series, Millstone grits, and Coal Measures form a whole, and consist almost entirely of detrital material. It seems possible to some extent to recognise life zones in this mass of rocks. It seems that

Anthracomya calcifera is characteristic of the Newcastle-under-Lyme series.

A. Phillipsii of the Blackband series.

A. Adamsii of the Burnwood ironstone.

Carbonicola acuta, *C. aquilina*, *Naiadites modiolaris* of the productive coal measures.

Carbonicola turgida is characteristic of the beds about the Moss Coal and the 5-foot. *C. robusta* of lower portion of the true Coal Measures. *Anthracomya Williamsoni* of the Hardmine Coal.

At the base of the Pendleside Series the beds contain *Prolecanites compressus.*

A little higher up beds with *Posidonomya Becheri* and *Pterino-pecten* come on. Still higher are black shales with *Posidonomya membranacea.* Then succeed beds with *Glyphioceras reticulatum* and *G. bilingue.* Higher up is a narrow band with *G. spirale* and *G. diadema.*

The Millstone grit shales and lower Coal Measures are characterised by *Gastrioceras Listeri* and *G. carbonarius.* This faunal succession is not confined to North Staffordshire but the same succession is to be found in Yorkshire and Lancashire in the neighbourhood of Pendle Hill. Some of the marine fossils of the Pendleside Series are found at various horizons in the Coal Measures, intercalated between beds with Carbonicola, as high as the Bay Coal of Longton.

MAY 31ST.

Director: DR. W. HIND.

The excursion was arranged to study the lower beds of the carboniferous sequence on Saturday, the whole series in succession on Monday, and the Upper Coal Measures on Tuesday. On Wednesday a return was made to the upper part of the Carboniferous Limestone to study some important details.

The party, who were joined by several members of the North Staffordshire Field Club, alighted at Thorpe Cloud Station, and on reaching the foot of Thorpe Cloud, the Director called attention to the contour of that hill and the change in scenery on the limestone and shale country. The probability that the course of the Dove was once on the eastern side of Thorpe Cloud, and that it had cut its present course later in the dale's history by underground solution and a falling in of the roof of the cavern, was mentioned. The question of the erosion of the dale by underground water was discussed, and beds of limestone lying on each side dipping towards the centre of the dale were pointed out as strong evidence of this view. Much was made of the evidence afforded by caverns at various levels of the work of the river in cutting out the dale. The massive character of the limestones, and the difficulty in making out the dip in the weathered rocks, were noted.

The party walked up the dale as far as the Doveholes, then ascending by Hall Dale to the high road to meet carriages, noticing that as the upper beds of the limestone were approached fossils became much more frequent.

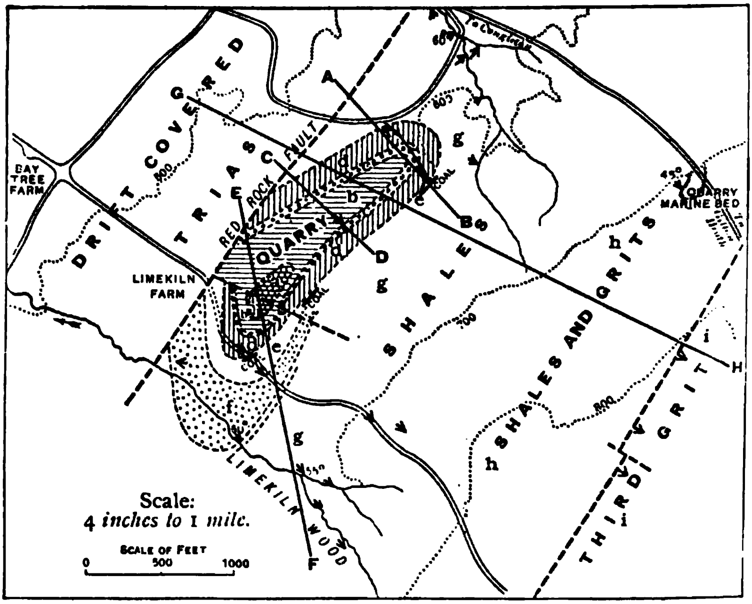

FIG 8.—SKETCH MAP OF A PORTION OF CONGLETON EDGE.

a. Limestone.
b. Shales and thin limestones.
c. Agglomerate and tuff.
d. Shales, limestones, and tuffs.
e. Shales with coal.
f. Grit.
g. Shales and thin earthy limestones.
h. Shales and grit.
i. Third grit.

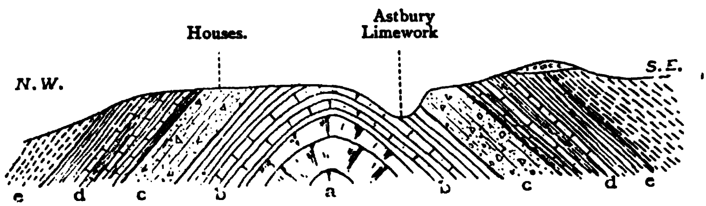

FIG. 9.—SECTION ALONG LINE C.D. OF THE MAP (FIG. 8) ON THE SCALE OF 25 INCHES TO THE MILE.

a. Limestones.
b. Shales and thin limestones.
c. Agglomerate and tuff.
d. Shales, limestones, and tuffs.
e. Shales with coal.

* Figs. 8-11 are reproduced from the *Q.J.G.S.* by the kind permission of the Council of the Geological Society.

Driving through Alstonfield the limestone quarry at Narrowdale was visited. The upper beds of the Carboniferous Limestone are exposed here and the locality is classical. Here Mr. Carrington, schoolmaster of the next village, Wetton, collected diligently for many years. Numerous fossils were found, but unfortunately, as quarrying operations were not going on, specimens were much less numerous than usual.

A short drive brought the members to the section of the upper beds of the Limestone at Apestor. The rolled shell bed is seen at the east end of the section, dipping to pass under black shales of the Pendleside Series, exposed in the river Manifold a few yards away. The thinly bedded limestones have been much faulted and repeated. A somewhat diagrammatic view of this section is to be found in the Memoir of the Geological Survey, "On the Geology . . . of North Derbyshire," p. 31. The section by the way being in Staffordshire, and the Director did not agree with the interpretation given.

A few members only examined the fine series of quarries below the village of Warslow, showing the upper 200-300 feet of limestone; the bed often containing nodules and strings of chert. The rolled shell bed which comes on at the top of this series was not visited, but it is exposed in a little quarry south of the road from Warslow to Hartington.

After tea the members drove towards Blakemere House and halting about a mile therefrom, descended into the gorge formed by the Elkstone brook, where a fine section showing the Pendleside limestone series was examined. The limestones exist as hard black compact rock bedded in black shales, and are better developed here than in any other part of the district, more nearly resembling the series on Pendle Hill. The Pendleside limestones are very variable and extremely local in character. Unfortunately, no fossils were found.

On the top of Morredge a halt was made while the Director pointed out the fine scenery produced by the Millstone grit series. The grits forming a concentric series of five escarpments, accentuated by the wearing away of the shale beds between the various grits. Quarries in Farey's grit, here a Crowstone, were noted on the descent of Thorncliff bank.

June 1.

Directors: Dr. W. Hind, Mr. W. Gibson, and Mr. C. B. Wedd.

The object of the day's work was to see the sequence of Carboniferous rocks from and including the upper beds of the Carboniferous limestone to the coal measures of the Biddulph Coal basin.

Alighting from the train at Mow Cop, a short walk brought the

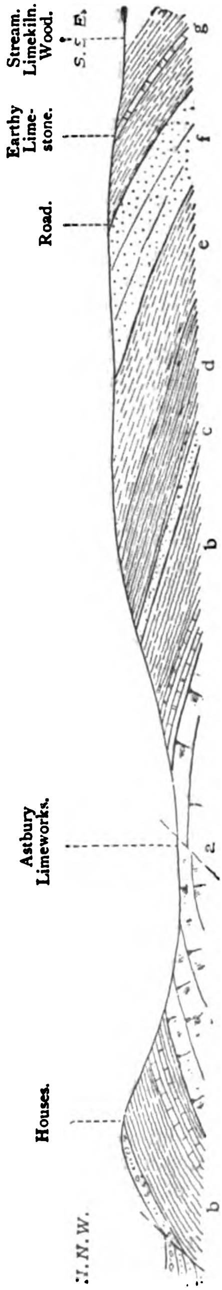

FIG. 10.—SECTION ALONG LINE E.F. OF THE MAP (FIG. 8) ON THE SCALE OF 20 INCHES TO THE MILE.

a. Limestone. *b*. Shales and thin limestones. *c*. Tuff. *d*. Shales. *e*. Shales with coal. *f*. Grit. *g*. Shales and thin earthy limestones.

members to the old limestone quarry near Astbury. Down in the middle of the quarry the upper beds of the limestone are seen dipping east. The limestone is in the form of a periclinal dome, cut off on the west by a fault, the Red Rock fault. On the east side of the quarry the series of shales and impure limestones forming the base of the Pendleside series were seen in section. These shales contain, as do similar beds at Pendle Hill, *Prolecanites compressus* and Trilobites and other fossils, including teeth of Cladodus and Orodus.

These also appear to be changed by heat, and in one section was seen a two foot bed of intrusive agglomerate exhibiting concentric weathering.

In the north end of the quarry is a mass of agglomerate of uncertain thickness containing chunks of marmorised limestone and occasional fossils which had been caught up in the molten mass. It is a question if this mass represents the vent or no.

It is, however, certain that the igneous action was contemporaneous, for in the stream a few hundred yards north of the quarry a series of ashy limestones, and stratified ash, occur interbedded with beds of purer material. Above the thin shales and limestones the Director pointed out two thin impure coals with their underclays which are overlaid by a sandstone. A move was made to Lime Kiln Wood, and the series of this limestone and shales of the Pendleside series were examined in the stream; then following a parallel stream the Crowstones and gannister-like sandstones in the upper part of the Pendleside series were examined, at the top

of which was a bed of shale containing *Gastrioceras Listeri*. An interval of a few yards then brought the members to the out-crop of the third grit, which forms the escarpment of the ridge of Mow Cop and Congleton Edge. Only the first and third grits are found here, the others having died away to the N.W.

A descent was then made to Hall & Sankey's quarry in the Crowstone series. The quarry is worked for gannister sandstone, which is ground up and forms an infusible material for lining the interior of furnaces.

The quarry shows the following section:

	Feet.
Dull grey and yellow clay with blocks of grit	0 to 5
Rotten Limestone made up of *Orthis resupinata*	5 " 2
Grit	1 " 0
Shales, grey	3 " 0
Shales. with slightly calcareous nodules	0 " 9
Hard, fine, grey sandy shales	0 " 4
Shales, with eleven bands of calcareous nodules containing a rich marine fauna	5 " 7
Rather dark shales, with two lines of calcareous nodules	3 " 0
Shales, with Goniatites	
Dark calcareous shales, with *Glyphioceras spirale*, *G. diadema*, *Posidoniella lævis*, and plants	1 " 0
Shales, with calcareous nodules, marine fossils	4 " 0
Coal about ½ in. twisted into joints of grit	0 " 0½
Gannister-like grit	5 " 8
Gannister grits and shales, with plant remains, all dipping 45° S.E.	33 " 7

The Quarry yields the following list of fossils.

BRACHIOPODA.

Athyris ambigua
Chonetes Laguessiana
Dielasma hastata
Discina nitida
Lingula mytiloides
L. scotica
Orthis resupinata
O. Michelini
Productus Cora
Pr. longispinus
Pr. scabriculus
Pr. semireticulatus
Spirifer glabra
Sp. trigonalis
Orthotetes crenistria

LAMELLIBRANCHIATA.

Aviculopecten gentilis
Actinopteria persulcata
Allorisma sulcata
Ctenodonta lævirostris
Edmondia rudis
E. Maccoyi
Leiopteria squamosa
Modiola transversa
Myalina peralata
Mytilomorpha rhombea
Nucula gibbosa
N. æqualis
Parallelodon obtusa
Posidoniella lævis
P. semisulcata
Pteronites augustatus
**Protoschizodus orbicularis*
Sanguinolites v-scriptus
Scaldia Benedeniana
Sedgwickia ovata

* A Bivalve specimen of this shell was found by the President.

CASTEROPODA.

Dentalium, sp.
Loxonema, sp.
Macrocheilina, sp.
(?) *Pleurotomaria monilifera*
Raphistoma junior
Bellerophon Urei
Bellerophon, sp.

CEPHALOPODA.

Ephippioceras bilobatum
Glyphioceras diadema
Gl. spirale
Orthoceras, sp.

CRUSTACEA.

Ceratiocaris oretonensis
Dithyriocaris testudineus

BRYOZOA.

Millepora interporosa, Phillips.

PLANTÆ.

Smooth stems, *Cordaites*.
Stigmaria, sp.
Trigonocarpon, sp.

(*Report by* MR. C. B. WEDD.)

On reaching the crest of Congleton Edge a good view was obtained of the syncline of the Biddulph valley, as defined by the ridges of the "First" and "Third" Millstone-grits, which

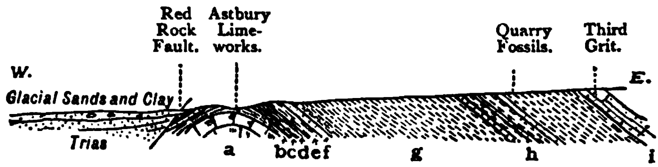

FIG. 11.—SECTION ALONG LINE G.H. OF THE MAP (FIG. 8) ON THE SCALE OF 4 INCHES TO THE MILE.

a. Limestone.
b-f. Shales, limestones, agglomerates, tuffs, and grit.
g. Shales and thin earthy limestones.
h. Shales and grit.
i. Third grit.

surround it on all sides but the south. The western limb of the fold has a much higher dip than the eastern, consequently the axis of the syncline, which nearly coincides with the bottom of the valley, except in the north, lies much nearer to the Millstone-grits on the west than on the east, and the axial plane is inclined downwards to the west. The fold itself pitches down to the south, but the valley drains northward.

The general distribution of the Drift was considered. Consisting of Boulder-clay, sand, and gravel, sometimes with fragments of marine shells, it fills an old drainage-valley coinciding with that of the Biddulph Brook. Thinning out east and south and west against rising ground, it is chiefly massed near the gap in the grit-ridges at Mossley, on the north-west side of the valley, where the present stream escapes.

In traversing the Coal Measures of the valley from the outcrop of their base at Congleton Edge to a point near the Falls Colliery, Gillow Heath, where the eastward dip is seen to give place to

a westward one, the outcrops of the several coal-seams and sandstones were noted.

In ascending sequence from the "First" Grit, a pebbly sandstone shows approximately the position of the Crabtree or Four-feet Coal, the chief seam of a small group of coals not far above the Grits, this group being succeeded by a broad belt of barren measures. After crossing these beds the party examined the course of an eastward-flowing stream, and noted the position of the coals in the lower part of the chief productive group of Coal Measures, the Winpenny, Bullhurst, Whitehurst, Eight feet Bambury (Cockshead or Newpool), Seven-feet Bambury (or Froggery), and Ironstone Coals in ascending order. The thick bed of *Carbonicola acuta*, a few feet below the Eight-feet Bambury, was examined, and specimens of *Carbonicola robusta* were obtained from the shell-bed a short distance above the Ironstone Coal, which crops out in the stream a few yards west of the synclinal axis. In another stream a little further south, at Moody Street Farm, the axis of the fold was seen again, but in higher beds, owing to the southward pitch of the syncline. Here the red sandstone beneath the Ten-feet Coal becomes nearly vertical before bending round the axis.

Between the two streams, the Biddulph Bowling Alley, Holly Lane, and Magpie Coals crop out in ascending order. A slight fall in the ground marks the outcrop of each, where they were formerly dug at the surface.

The party then adjourned to the Biddulph Arms Hotel, where tea was provided, and afterwards returned by special train to Congleton, and thence to Stoke.

JUNE 2ND.

Director: MR. W. GIBSON.

(*Report by* THE DIRECTOR.)

Tuesday morning and early part of the afternoon were employed in examining several sections of interest, but of a somewhat disconnected character, in the more immediate neighbourhood of Stoke-upon-Trent.

Driving at a very funereal pace from Stoke to Trentham the magnificent quarry in the Bunter Conglomerate at the north end of Trentham Park was first visited. Here an excellent opportunity of seeing the beds of contained shingle was afforded. The igneous dyke traversing the Bunter Sandstone in the Hanchurch Hills and the Keele Series in Butterton Park were next visited. From Butterton to Keele Park Racing Station the route lay over the Higher Coal Measures, much faulted. At the Racing Station a long cutting in the Keele Series was examined, and the limestone in their midst, containing *Spirorbis*,

found without much difficulty. From this point the members were driven *via* Keele Village to Basford, where the party divided: the greater number returning to Stoke, a few going to the Grange Colliery, and the remainder, with the leader, walking northward to Longport. The latter had an opportunity on the way of examining the large quarries near the summit of the Etruria marls. In the pit near Longport the limestone at the base of the Newcastle-under-Lyme Series yielded good specimens of the small shell *Carbonicola calcifera*.

It had been arranged that the party should proceed from Longport to the Grange Marl pit where the lower portion of the Etruria marls are quarried, and thence to continue downward in the sequence through the Black Band Series into the Productive Measures. Time and the slow rate of driving in the early part of the day unfortunately put a stop to this, as the members were due to a reception in the evening by the North Staffordshire Mining Institute and the Naturalists' Field Club.

June 3rd.

Directors: Dr. W. Hind and Mr. R. Fane de Salis.

(*Report by* Dr. Hind.)

The Association were this day practically the guests of the North Stafford Railway, and were accompanied by several directors of the line, the general manager, Mr. W. D. Phillips, and the engineer, Mr. Crosbie Dawson. The excursion was a joint one with the N. Stafford Field Club, who turned out about forty strong. Travelling by special train the first halt was made at Froghall to examine a marine-band with *Pterino-pecten papyraceus* and *Posidoniella lævis* near the base of the Cheadle coalfield.

An ascent was then made by the funicular railway to the great limestone quarry of Cauldon Lowe, passing over Lower coal measures, Millstone grits, and Pendleside series. The beds at Cauldon Lowe quarry are characterised by *Productus humerosus* and *Chonetes papillionacea*. Some large gasteropods, *Naticopsis*, *Platischisma*, *Bellerophon aspectus*, and *B. cornu-arietis* occur as casts of the interior. The presence of these species of *Bellerophon* in Lancashire and Yorkshire denotes beds very low down in the Carboniferous limestone. One lamellibranch, *Myalina Redesdalensis* has been found there.

Arrived at the quarry Mr. R. F. de Salis gave an account of the economics of the limestone, and described how it was worked. A large blast of about 25,000 tons had been prepared, and this was duly fired, bringing down a large mass of the quarry face.

The following is a copy of the Analyst's Report upon the limestones of Cauldon Lowe Quarry:

Public Analyst's Laboratory, Wolverhampton,
August 15th, 1894.

Certificate to North Stafford Railway Company of Samples of Cauldon Lowe Limestone.

	No. 1. Blue.	No. 2. White.
*Lime	55.40 ...	55.35%
Magnesia	0.47 ...	0.47
Alumina and Oxide of Iron ...	Trace ...	Trace
Silica	0.45 ...	0.35
Phosphorus	Trace ...	Trace
Sulphur	Trace ...	Trace
Carbonic Acid, etc.	43.68 ...	43.83
	100.00	100.00

* This equals pure carbonate of lime, 98, 91, and 98, 84%.

Analysis proves these limestones to be of practically the same composition of very good quality, and specially suitable for fluxing or chemical requirements.

(Signed) E. W. T. JONES, F.I.C.

Before leaving the Quarry the President proposed a vote of thanks to the Directors of the Excursion, and also to the Directors of the North Staffordshire Railway.

The next object of interest was the sand and clay pit. The Director described the general character of similar pits and their distribution in the limestone district, pointing out that the contents of the pit examined consisted of re-arranged Bunter gravels, blocks of Triassic sandstone, masses of Pendleside shales, together with sand and clay. The place was evidently an old swallow hole, which had got filled with the material brought down by the stream which disappeared down it.

After lunch the series of quarries at Waterhouses which show a continuous section of the upper 700 feet of Carboniferous limestone were visited. The lowest beds are almost vertical, and make a good hydraulic lime, and are evidently faulted against more massive limestone, the dip gradually diminishes, as is seen in the quarries on each side of the Hamps. Many fossils were noticed, *Lithostrotion aranea* and other corals, many Brachiopods and the tooth of *Psamodus porosus* and *Petalodus Hastingii.* The upper beds of the limestone are most interesting, showing two beds of rolled shells, separated by a less shelly limestone. The characteristic rolled fossil being *Productus giganteus* and its varieties. In the River Hamps, at the back of the school, the limestone is seen dipping beneath a series of shales and limestones, and further up the stream is a mass of black shales with fish remains and *Posidoniella lævis.* Whether this junction of the Carboniferous limestone and the Pendleside series is a true one or no is not quite certain.

A move was then made for the new railway, and the cuttings in Pendleside shales and sandstones were examined. The line, about 8 miles in length, starts at Leek Brook, in Bunter sandstone

which are faulted against Pendleside series on which it runs unti the limestone is reached at Waterhouses and Cauldon. The Pendleside series are much faulted, bent and repeated and the succession is difficult to make out on that account. A special train waiting at the junction with the main line rapidly conveyed the members to Stoke in time to catch the official train for London, and brought the excursion to a close.

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CYCLING EXCURSION TO THE ALDERSHOT DISTRICT.

JUNE 6TH, 1903.

Director: THE PRESIDENT (HORACE WOOLLASTON MONCKTON).

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* THE DIRECTOR.)

The party assembled at Farnborough Station (L. & S.W.R.) at 3 p.m. and cycled by way of Mitchet House to Tunnel Hill, a part of the Fox Hills. After examining a road cutting and a railway cutting they proceeded in a northerly direction to Deep-Cut Bridge and on to Chobham Ridges, where two gravel pits were visited. Both these pits are on the plateau a little north of Blackdown Barracks. Leaving them the party cycled along the top of Chobham Ridges to the Jolly Farmer Inn on the London Road.

A vote of thanks to the Director was proposed by Mr. H. J. Osborne White, and the members separated.

The main object of the Excursion was to study Sarsen Stones, and several of these stones were seen by the members in place in

the sections. That is to say they were partially uncovered but had not been moved in recent times. There does not appear to be any record of sarsens in place having been seen on a former excursion of the Association to this part of England.

Though these stones had not been moved in recent times it would perhaps not be accurate to say that they were *in situ*, for they all bore signs of water or weather wear in former times, and, indeed, there does not seem to be any definite record of a sarsen ever having been seen *in situ*. Possibly a sarsen *in situ* would not be a sarsen.

The following sections were visited. The names have for the most part been recently given by the military authorities and are not to be found on the present maps.

1. ROAD CUTTING ON THE EAST SIDE OF THE FOX HILLS AT LONGDOWN HILL.

The section shows some thickness of sand belonging to the Upper Bagshot Beds. A bed of gravel (Southern Drift of the Fox Hills Plateau) rests irregularly on the sand, and the upper part of the sand under the gravel looks as though it had been somewhat re-arranged before the gravel was deposited on it.

The gravel is well stratified, current-bedded, and is probably a river gravel. Two sarsens were seen in place in the cutting. The first on the north side, 2 ft. 4 in. in length and 1 ft. in thickness, lay close to, but not quite at, the bottom of the gravel. It had a slight tilt to the south, the direction from which the river probably flowed. The second sarsen was on the south side of the road cutting and was also tilted to the south. It measured 3 ft. 4 in. by 1 ft. 2 in., and projected 1 ft. 10 in. from the side of the cutting. It appeared to rest on the sand below the gravel, but was otherwise surrounded by gravel.

2. SECTION ON THE BRANCH LINE OF THE SOUTH WESTERN RAILWAY BETWEEN BROOKWOOD AND NORTH CAMP STATIONS.

The locality is now known as Tunnel Hill.

The beds shown are as follows:

1. Gravel similar to that in the road cutting described above.
2. Upper Bagshot Beds.

	ft.
(*a*) Dark yellow sand passing down into sand of a lighter colour; numerous *casts of shells* throughout ... about	20
(*b*) Bright yellow sand ... ... about	½
(*c*) Yellow sand with *casts of shells* ... ... about	14
(*d*) Nearly white sand with a layer of dark yellow patches. *Casts of shells* very numerous ... ... about	13
(*e*) Variously tinted sands with but few *casts of shells* about	40

3. SECTION ON THE MAIN LINE OF THE SOUTH WESTERN RAILWAY NEAR DEEP-CUT BRIDGE.

A great thickness of sand belonging to the Upper Bagshot Beds was seen, and at what appeared to have been the original surface of the ground a sarsen with a little gravel below it was observed. The side of the stone exposed measured about five by two feet.

This stone lies in the valley between the Fox Hills and Chobham Ridges, and, in fact, sarsens are found at all levels in this district, though always at or near the surface of the ground.

4. GRAVEL PIT ON THE TOP OF CHOBHAM RIDGES A LITTLE NORTH OF BLACKDOWN BARRACKS.

Several sarsens were seen in place. The most interesting was in the gravel on the south side of the pit, standing almost on end. It appeared to touch the sand at the bottom of the gravel and projected about 3 ft. up into the gravel. Above its top there was about 4 ft. of gravel. The Director thought its remarkable position might be due to ice floating down the river by which the gravel was deposited.

Other stones over 4 ft. long were seen in the sides of this pit. They usually had a little gravel beneath them and some 5 ft. of gravel above them, and they were tilted in various directions, one to the north, another to the south, another to the south-east. Attention was drawn to one surface of one stone which was covered with small perforations, no doubt due to small roots.

5. GRAVEL PIT ON THE TOP OF CHOBHAM RIDGES A LITTLE WEST OF THE LAST PIT AND SOUTH OF THE ROAD FROM BLACKDOWN BARRACKS BY "THE FIRS" TO FRIMLEY.*

Several sarsens were seen in place in this pit. One small stone being several feet above the bottom of the gravel, a position so unusual that the section at the spot seems worth recording.

1.	Surface turf	$\frac{1}{3}$ ft.
2.	Gravel	$2\frac{1}{2}$ "
3.	Sarsen stone	1 "
4.	Gravel	$\frac{1}{2}$ "
5.	Coarse sand, well stratified	$1\frac{1}{4}$ "
6.	Gravel	$1\frac{1}{2}$ "
7.	Sand on floor of pit, probably Upper Bagshot ...	

The Director remarked that the river which formed the gravels of the Fox Hills and Chobham Ridges must have drained a much

* It is the pit described by the Director as being on Jackpond Hill in a paper in the *Quart. Journ. Geol. Soc.*, vol. liv (1898), p. 189.

more extensive area than the modern Blackwater, for these gravels contain an abundance of fragments from the Hythe Beds of the Lower Greensand, whose nearest outcrop is away south of the Hogsback and now within the drainage area of the River Wey.

The gravel of the Blackwater and of the terrace at Mitchet Lake, to which attention had been drawn, also contains Lower Greensand fragments, but they may have been derived from the gravels of the plateaux; at the same time we can scarcely look at the wide spread of gravel along the Blackwater, which extends up the river as far as Ash, without feeling sure that the river had at the time a much greater southern extension than it has at the present day, and it is probable that the River Wey has gained drainage area from the Blackwater, just as the River Severn has gained on the Thames.

The abundance of Lower Greensand fragments continues to be a marked feature of the gravels along the sides of the Blackwater and of the Loddon, after the Blackwater has joined it, as far as its junction with the Thames, and as there is very little gravel near the upper part of the Loddon it is clear that the sheets of gravel between Swallowfield and Wargrave are far more closely connected with the Blackwater than with the Loddon.*

With regard to the sarsens the Director said he did not believe them to have been derived from any definite band of rock. He thought that they were relics of an old land surface. He remarked that the shells of Lower Barton species found at Tunnel Hill are the last sign of the presence of the sea in this part of England. Of the succeeding Middle and Upper Barton, Oligocene, Miocene, and Pliocene, we have here no sign, so that at some time during the long period which has elapsed since Lower Barton days this area must have become land, and it probably remained for ages as a wide flat covered by vegetation, marks of the roots of which we now see in the sarsens. They themselves are probably due to the action of organic acids, due to the vegetation, upon the sand at the surface of the ground.†

When elevation of the land took place the rivers and streams would cut their channels down to lower levels, and in course of time the old surface would be destroyed and the indurated fragments which we call sarsens would slip down into the valleys, and in many cases become buried in the river gravel where we now see them.

As from time to time further movements of elevation took place the rivers deepened their channels still further by cutting away the soft sandy sides of the valleys in preference to the more solid ground, and in many cases the gravel which once filled the bottom of a valley has thus become the capping of a hill or a

* See J. H. Blake. Geol. of the Country around Reading. *Mem. Geol. Survey*, 1903, 79.

† See Hudleston, *Proc. Geol. Assoc.*, vol. vii, p. 138, and Irving ib., vol. viii, p. 156.

plateau, whilst in others it remains as a terrace along the side of a valley.

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EXCURSION TO DENHAM AND GERRARD'S CROSS. TO THE NEW CUTTING ON THE GREAT WESTERN RAILWAY.

JUNE 13TH, 1903.

Director: J. ALLEN HOWE, B.SC., F.G S.

Excursion Secretary: E. W. SKEATS, D.SC., F.G.S.

(*Report by* THE DIRECTOR.)

In spite of a steady downpour all the afternoon, a small number of enthusiasts attended and carried out the whole of the programme.

The party on leaving Uxbridge Station walked through the town and thence along the canal towing-path towards the excavations which have recently been made through the thin alluvium of the Colne into the gravel beneath it. The Director here pointed out that the river Colne between Harefield and Colnbrook now runs over a deposit of gravel which has probably an average thickness of 10—15 ft. Lying upon the gravel there is usually a layer of peat or peaty soil, with occasional patches of shelly marl.

Search was made in the marl upon the refuse heaps, and Mr. A. S. Kennard, who examined the finds, sends this note—

"The following species of mollusca have been obtained from the shell marl:

Vitrea crystallina	*Helix aspersa*
,, *nitida*	,, *nemoralis*
,, *radiatula*	,, *arbustorum*
Arion ater	*Clausilia bidentata*
Vallonia pulchella	,, *laminata*
Acanthinula aculeata	*Cochlicopa lubrica*
Pyramidula rotundata	*Pupa muscorum*
Hygromia granulata	*Succinea elegans*
,, *hispida*	*Ancylus fluviatilis*

Velletia lacustris	*Limnæa palustris*
Bithynia tentaculata	" *truncatula*
Valvata piscinalis	*Planorbis albus*
" *cristata*	" *spirorbis*
Limnæa stagnalis	" *contortus*
" *pereger*	*Pisidia*

"Of these the most noteworthy are *Helix aspersa* and *Acanthinula aculeata*. The former species was for long considered to be a Roman introduction into these islands, but it has lately been shown to be indigenous and to belong in all probability to the so-called Lusitanian group, though very likely its range has been extended accidentally by man. The latter form, though a widely distributed species at the present time, is rather rare in deposits of any age.

"Bones of ox, horse, sheep, pig, and dog, probably all modern, also occurred."

Flint flakes and old cores were found scattered over the recently exposed gravel and Mr. Kennard furnishes the following remarks upon them :

"In this excavation resting on top of the gravel and beneath the alluvium an immense number of marked flints were obtained. They did not occur all over the area, but only in one spot; whilst they are all stained a rich brown by the peat. The majority have been made from flint obtained direct from the chalk, and the nearest locality is about two miles away.

"The whole facies of the implements resembles those described by Mr. W. J. Lewis Abbott, F.G.S., from Sevenoaks and Hastings, but in some respects they are nearer to the "Cave" implements. As at Hastings the chief aim of the flint worker was to produce a pointed flake and such was probably attached to a stick as a spear or javelin head. Many of the broken bases were found as well as many wasters, but perfect flakes as may be expected were extremely rare. Some of the flakes and tools are very large and are indistinguishable from Palæoliths. The implements found are nearly all well-known cave types. The exact age is doubtful. They must be newer than the third terrace on which they rest and older than the alluvium, but whether they belong to the last stage of the Pleistocene or the early part of the Holocene is doubtful, though judging from the implements they belong to the former."

(Since writing the above, Mr. Kennard informs me that he has made a second visit to the spot, and has now taken away 1,500 flakes.—J.A.H.)

After leaving the canal to follow the new railway line towards Wycombe, the broad terrace of the Colne which lies north of Denham village was traversed, and about Bailey Hill the first cutting was entered. Here the gravel of the plateau is well

exposed, resting upon mottled Reading Beds, which were not very clearly visible owing to the rain; somewhat further west, near the Rolls farm, the same gravel was seen resting upon the London Clay, and from it a few specimens of *Panopæa intermedia* and *Meretrix orbicularis* were obtained.

It was pointed out by Mr. Sikes that this section will be better seen when the cutting has been made deeper and the way in which the gravel passes from the top of the London Clay on the west to the top of the Reading Beds on the East will then be made clear.

The party then proceeded across the new viaduct over the Misbourne, and here the Director indicated the position of a considerable deposit of shell-bearing travertine and marl in the old bed of the stream where the water has now been diverted into a new course.

On the western side of the valley the chalk was seen in a small pit near the road to Chalfont, and an interesting example of hill-creep, with wisps of gravel caught up in the loam was noticed on the slope of the hill. Further on, the cutting showed a splendid section in the plateau gravel—about 25 feet thick—with well-marked current bedding and patches of sand at various levels; but here, as on the other side of the valley, this sandy character is better developed in the lower portions of the gravel.

There being no time to look at the fine exposure of Reading Beds beyond Gerrard's Cross the party left the cutting to examine the very interesting collection of London Clay and other specimens from the excavations made by Mr. R. C. Sikes.

After tea at Gerrard's Cross a vote of thanks was proposed to Mr. Sikes and the Director, and the party then drove back to Uxbridge.

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EXCURSION TO THE LIGHT RAILWAY BETWEEN KELVEDON AND TOLLESBURY, ESSEX.

JULY 4TH, 1903.

Director: T. V. HOLMES, F.G.S.

Excursion Secretary: H. KIDNER.

(*Report by* THE DIRECTOR.)

By the kind permission of the contractors, Messrs. Walter Scott and Middleton, Ltd., a visit was paid to that portion of this railway now in process of construction which lies between Kelvedon and Tiptree.

Its northern end is close to Kelvedon Railway Station, and its course, for about the first 300 yards, is close to the G.E.R. line, and on its southern side. Then the Light Railway crosses Feering Hill about 350 yards south-west of the junction with the road to Inworth and Tiptree, and ranges in a S.S.E. direction, westward of that road, as far as Tiptree.

The portion of the railway visited is wholly in Sheet 47 of the map of the Geological Survey, and near its south-eastern boundary. The first section observable after leaving Kelvedon Station was where the Light Railway begins to diverge from the G.E.R., and was in reddish gravel. This gravel was seen both north and south of Feering Hill, though chiefly northward. At one spot, near the northern end of this gravel-cutting, a little Boulder Clay could be seen beneath the gravel. This Boulder Clay is evidently a portion of the narrow band shown on the map of the Geological Survey in the midst of the post-Glacial gravel of the Blackwater Valley, which is traversed by the Light Railway at this point. In the Memoir on Sheet 47 Mr. W. H. Dalton thus refers to it (p. 67): *

"Between Feering and Kelvedon the gravel has been denuded in such a way that the Boulder Clay is exposed as a narrow belt skirting the brow of the hill."

Between Feering Hill and Domsey Brook this gravel was the only bed visible. And before leaving it, it may be well to note that on the day of our visit it was well shown, with the Boulder Clay beneath it, in the cutting on the G.E.R. Main Line, close to, but west of, Kelvedon Station, as far as Rolleylane Bridge.

Crossing Domsey Brook the party entered a cutting wholly in Boulder Clay, which had a length of about 400 yards. From a drain ranging from the northern end of this cutting to the

* Explanation of Sheet 47 of the Map (1-inch) of the Geol. Survey. By W. Whitaker W. H. Penning, W. H. Dalton, and F. J. Bennett.

alluvium of Domsey Brook it became obvious that the Boulder Clay extended downwards at least as far as the level of the brook. And the Director, when making some remarks on the local geology from a spot above this cutting, noted the following statement in the memoir on sheet 47, bearing upon the depth probably attained by the Boulder Clay at this part of the new line. It refers to a brickfield close to the Inworth Road, about 500 yards eastward, and south of Domsey Brook (p. 62):—

"The 'Clay Pit' marked on the Ordnance map, between Feering and Inworth, is a brickyard, worked in Boulder Clay (the upper part whitish, the lower dark blue) to a depth of at least 30 ft. It is then not bottomed, and therefore the base must be some depth below the river, and the clay is probably continuous across the valley to Kelvedon, as at Witham, though overlaid by Valley Gravel in both cases. Between Feering and Witham, indeed, the Boulder Clay sinks down, cutting out the underlying Glacial gravel, and resting on the London Clay."

Beyond this cutting, small drains beside the line showed Boulder Clay at the surface as far southward as a point due west of Inworth Church. Then south-west of the Rectory, at the south-eastern corner of a field the eastern hedge of which ranges close to, but west of, the railway, a sarsen stone was seen. And from this point, to that at which the Light Railway crosses the road from Inworth Grange and Windmill Hill to Tiptree, London Clay, with irregular cappings of gravel, appeared. The party did not proceed beyond the road just mentioned.

The London Clay near the north-western corner of Perry Wood showed septaria nodules with very high and irregular dips in a horizontal space of about 25 yards, suggesting the presence of one or more faults. As Mr. W. Whitaker remarked, the position of this spot is worth noting, as it may possibly turn out to be on the line of the Wickham Bishop or some other important fault. In Essex the absence of hard beds and the very large proportion of the country which is covered by superficial deposits make the detection of the direction taken by lines of fault a work of exceptional difficulty.

Of the gravel patches capping the London Clay hereabouts, the only one deserving special mention was seen between New Barn westward and Hill Farm eastward of the line. It was much coarser than the other patches, and contained many large flints.

The party returned to Kelvedon by the road from Tiptree past Perry's Wood and Inworth Church; and after tea at the Sun Inn, on Feering Hill, caught the 7.35 p.m. train for Liverpool Street.

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EDITED BY

J. ALLEN HOWE, B.Sc., F.G.S.

(Authors alone are responsible for the statements in their respective Papers.)

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"On the Eocene and Oligocene Beds of the Paris Basin."

By GEO. F. HARRIS, F.G.S., and H. W. BURROWS, A.R.I.B.A.

This Paper comprises:—(1.) A detailed **Description of the Beds,** the result of several years' careful study of the Parisian Tertiaries and close communication with many eminent French geologists. (2.) A practical **Guide for the Field-Geologist** to all the best exposures, based on personal experience. (3.) A Revised **List of the Mollusca,** showing their range in time, with Lists of other Fossils.

(*Continued on page 3 of the Cover.*)

THE ZONES OF THE WHITE CHALK OF THE ENGLISH COAST.

By Dr. ARTHUR W. ROWE, F.G.S.

THE MAPS AND CLIFF SECTIONS by C. DAVIES SHERBORN.

IV.—YORKSHIRE.

[PLATES XVII to XL.]

(Read May 1st, 1903. Issued February, 1904.)

THE WHITE CHALK OF THE YORKSHIRE COAST.

From Speeton to Bridlington.

CONTENTS.

INTRODUCTION.

THE Yorkshire coast, replete though it be with rugged grandeur, relieved here and there by spots of softer beauty, has been one which has been severely left alone by zonal geologists. Nor, indeed, is the reason for this course far to seek. From the time of Phillips* onwards the section has appealed far more to the physical geologist than to the palæontogist, chiefly on account of the inaccessibility of the coast—miles of the Headland being totally unworkable—and the notorious scarcity of fossils.

We have long cherished a furtive ambition to explore this mysterious and legendary coast, but have deliberately refrained from so doing until such time as we had been able to study the bulk of the White Chalk in the South of England, so that haply we might arrive at some idea as to the average or normal in the distribution of the fossils in the various zones. To attack this northern problem, even with a full knowledge of one of the richest of the counties, such as Kent or Sussex, would be but to court inevitable failure. Nothing short of a fair working knowledge of all the permutations and combinations, of all the idiosyncrasies of zonal distribution in the south, would give us the faintest chance of reading the riddle of the north.

We spent our holidays in the spring and autumn of 1902 at Bridlington Quay, devoting 42 days of steady work to the section. The time given we feel to be hopelessly inadequate; but as the scope of this paper is confessedly limited to a tentative, rather than an exhaustive, examination of the coast and its fauna, we are content to await further opportunities for filling in the gaps in our zoological record, and for correcting measurements and zonal junctions. We worked the section twice over, yard by yard, repeating our observation many times in all difficult or interesting exposures. In addition, we examined 39 chalk-pits, chiefly in the neighbourhood of Flamborough Head. So that our knowledge of the fauna should be

* Phillips, "Geology of the Yorkshire Coast." 2nd Edition, 1835.

as intimate as our brief visits would permit, we collected 1850 fossils from the coast and adjoining quarries—a scanty material, it is true, for southern sections, but the best that we could do in a limited time in this relatively barren area.

There is a glamour and fascination attached to the unknown, which, coupled with the acknowledged difficulties of a coast like this, greatly adds to the zest of the work. For this coast is unknown. It is a veritable *terra incognita.* It may savour of presumption to call this region unknown, when Dr. Barrois has described it in his incomparable monograph, when the literature on the subject has been enriched by the labour of Professor Blake, Mr. Dakyns, Mr. Fox-Strangways, Mr. Lamplugh, and Mr. William Hill, and when the whole coast-line has been assiduously explored by many keen and capable Yorkshire geologists. Still, the fact remains that, however well the physical features may have been worked out, until the fauna has been thoroughly examined and systematised, the section is as a sealed book.

Dr. Barrois's great work* is the only one which contains a serious attempt to grapple with the zonal problems of this coast, and for once, we must frankly own, we cannot follow him in his data or conclusions. Let it be remembered, however, that he did not spend as many days as we devoted weeks to the section. When we read his account of this area we can only wonder that he was able to cover so great an extent of ground, and to collect so many reliable zoological facts. There is another interesting communication on this section by Professor Blake,† but this does not greatly advance our knowledge of the zones as a whole, as he falls back upon a division of the White Chalk on evidence obtained from the nature of its flints. There are, however, many useful zonal records, chiefly of fossils in the Mortimer Museum, and in greater part relating to the zone of *Actinocamax quadratus.*

In *Proc. Geol. Assoc.*, vol. vi, pp. 165-170, is a reply by Dr. Barrois to Mr. Blake's paper, entitled "Note on the Rev. J. F. Blake's paper on the Chalk of Yorkshire," and this is followed by a "Reply by the Rev. J. F. Blake." Dr. Barrois's note is of interest in that he discusses the Inocerami of Yorkshire, and mentions two other forms which do not occur in his "Recherches," namely, *Inoceramus* cf. *cuneiformis* (d'Orb., Pal. Franc., p. 512, pl. 407) and *Inoceramus undulatus* (Mantell, *vide* Goldfuss. "Petref. Germ," pl. 112, fig. 1). The former figure resembles some of the forms found in the *gracilis*-chalk of Speeton, though none of our examples have the umbo sufficiently preserved to make the determination certain; and the latter

* C. Barrois. "Recherches sur le Terrain Crétacé supérieur de l'Angleterre et de l'Irlande." Lille, 1876.

† J. F. Blake. "On the Chalk of Yorkshire." Proc. Geol. Assoc., vol. v, No. v, 1887.

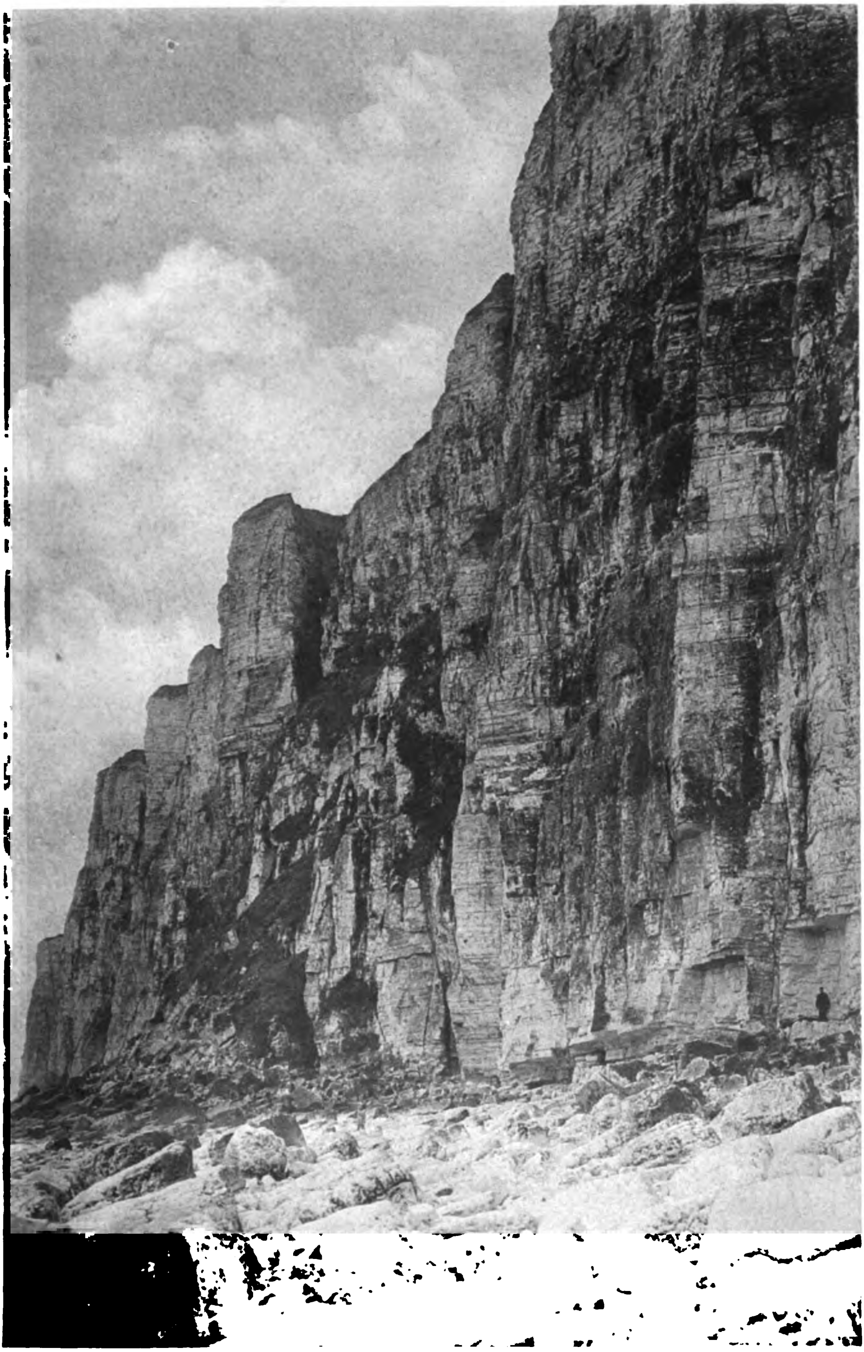
figure closely corresponds to our solitary example from the *quadratus*-beds of Sewerby Cliff, mentioned on p. 269. Speaking of the zone of *Marsupites*, and alluding to the occurrence of *Nautilus*, *Scaphites*, *Hamites*, and *Avicula tenuicostata* recorded by Mr. Blake, Dr. Barrois says: "This is my Bridlington Chalk." The presence of these forms "clearly indicates that several minor sub-divisions could be traced in this mass of Chalk 300 ft. in thickness, which might easily be compared with those of Prof. Schlüter, who found the same fauna in the north-west of Germany." Dr. Barrois was, therefore, quite aware that fossils identical with the German *quadratus*-fauna occurred in the Bridlington Chalk (see "Recherches," pp. 198-199), though in his Memoir he referred the whole of the flintless beds to the zone of *Marsupites*.

It is wholly impossible to institute any valid comparison between this marvellous coast and any of the sections which we have previously described. For, alike in the hardness of the rocks, in the peculiar lithological conditions of the beds, in the paucity of fossils, in their deplorable state of preservation, and in their strange and unwonted distribution, we find no parallel to it on our English shores. It is unique—a thing apart.

And just as this coast is distinguished from all other English sections by the nature of the rocks, and to a large extent by the identity and distribution of its fossils, so does it differ in mere physical conformation. Leaving out of consideration the Red Chalk and the Drift, the cliffs themselves are quite unlike those on our southern shores. Those on the south of Flamborough Head, it is true, may be matched, save for the Drift, and the complete absence of flint, with the cliffs between Newhaven and Brighton; but we have no counterpart in the South of the grand screes of Speeton, nor are our southern cliffs, however lofty, comparable to the mighty tide-bound ramparts of Bempton. But the chief glory of the Yorkshire coast lies in its bays. Thornwick, North Sea Landing, and Selwicks display a beauty so rare that they compel the admiration of the most careless; and that beauty is enhanced by the fact that the presence of these bays is so unexpected. Our only disappointment is that, by reason of the mantle of seaweed, they offer so poor a ground for the collector.

A coast which can display 555 ft. of flint-bearing chalk, and 547 ft. of flintless chalk, is sufficiently unusual to arrest attention; and when we add that the pits in the Bridlington area afford us possibly another 150 to 200 ft. of the latter, we have indeed a section of surpassing interest.

We must remember, also, that the whole of the cliffs south of Flamborough Head are cut in flintless chalk, and that all north of that point are in flinty chalk, save the attenuated zone of *Rhynchonella cuvieri*, and the beds below that horizon, with which this paper does not deal.



SECTION WEST OF KIT PAPE'S SPOT,

Near the eastern limit of the Buckton Cliffs, shewing the position of the vertical fault, the overthrust fault, and the "black band."

Mr. Lamplugh's* measurements are vastly in excess of those given by Dr. Barrois and Professor Blake, but we believe them to be substantially accurate. That Dr. Barrois,† even with his smaller measurements, should have assigned the whole of the flintless chalk south of Flamborough Head to the *Marsupites*-zone was on the face of it too striking a divergence from the normal to obtain unquestioned assent. We now know that three zones are exposed in this flintless chalk, ranging from the zone of *Micraster cor-anguinum* to that of *Actinocamax quadratus*. On the north side of Flamborough Head, in the flinty chalk, we can trace the zones of *Rhynchonella cuvieri*, *Terebratulina gracilis*, *Holaster planus*, *Micraster cor-testudinarium*, and the flinty base of the bed of *Micraster cor-anguinum*. These conclusions are not speculative, but are in every case obtained from definite zoological data, and can in every instance be readily checked by other observers.

That this section presents many physical difficulties we readily admit, but we question if they are as insuperable as has been maintained. On the north side of Flamborough Head we have defined the limits of the zones of *Rhynchonella cuvieri* and *Terebratulina gracilis*, and of the latter and *Holaster planus;* but have failed to fix the junction lines of the zones of *Holaster planus* and *Micraster cor-testudinarium*, or of the last named, and *Micraster cor-anguinum*. This failure is due to the simple reason that the cliffs are sheer and tide-bound in this situation. But on the south side of Flamborough Head no such difficulties present themselves. With an ordinary knowledge of the fauna anyone can readily separate the zones of *Micraster cor-anguinum*, *Marsupites testudinarius*, and *Actinocamax quadratus*, and fix the zonal boundaries within one or two feet. Indeed, we zoned the whole of the flintless chalk south of High Stacks in five hours. Naturally we could not, in such a rapid traverse of this section, fix any limiting lines; but we obtained all the requisite zoological data, and subsequent systematic collecting only served to confirm our primary conclusions.

Bridlington Quay is the natural centre from which to work this area, for all sections in the neighbourhood of Flamborough are within easy walking distance, and more distant places, such as Speeton, Driffield, Beverley, and Hessle are easily reached by train. From Speeton we can reach the section at Kit Pape's Spot, where the zones of *Rhynchonella cuvieri* and *Terebratulina gracilis* are exposed, as well as the Speeton Cliffs, which display the zones of *Terebratulina gracilis* and *Holaster planus*. Several important chalk-pits, such as Nos. 1, 2, 3, 4, 5, 11, 13, 14, 15, 16 and 17 of our map, are best reached from the same station.

* G. W. Lamplugh, "Notes on the White Chalk of Yorkshire," *Proc. York. Geol. and Polyt. Soc.*, vol. xiii, Part I, 1895.

† *Op. cit.*, pp. 196, 197.

It is well to remember that some of the most convenient trains do not stop at Speeton; but a letter to the courteous traffic manager at York will usually secure the stopping of a train, if due notice be given.

No visit to this area would be complete without a visit to the famous Mortimer Museum at Driffield. It is a veritable treasure-house of archæological and palæontological relics, and forms a permanent monument to the knowledge and untiring energy of its founder, Mr. J. R. Mortimer, and his brother, the late Mr. R. Mortimer. The chief value of this collection lies in the fact that it is purely local in its scope, being incomparably the finest series of East Yorkshire fossils in existence. The high value of the material is much enhanced by the fact that each exposure is plotted-out on the 6-inch map, and that nearly all fossils have a corresponding reference to the spot from which they were obtained. The collection is in no sense a zonal one; but with the references to locality it would not be a long or difficult task to accurately zone the bulk of the fossils. Indeed, from this collection alone, it would be possible to write a fairly comprehensive account of the fauna of this area.

Speeton to Kit Pape's Spot.

Not only is this one of the most difficult sections to read, alike from the rarity of the fossils and inaccessibility of the beds, but it is without exception* the most arduous to accomplish, for we have to traverse $2\frac{1}{2}$ miles of rock-strewn shore, stepping from boulder to boulder the whole way. Some idea of the appearance of the shore is given in Pl. XVII, and the tedious nature of the walking may be inferred from the fact that this short distance occupies $1\frac{1}{2}$ hours. It is imperative also that the tide be taken into consideration, as the seas are very heavy, and the water comes up rapidly. There is one unnamed projection of the cliff, formed by a great foundered mass, which we cannot pass until the tide has fallen considerably. For our own part, we prefer to work the cliffs east of this projection on a falling tide.

To understand this section aright we must leave the Speeton Cliffs to be examined on the way back, and walk along the shore to the extreme end of the Buckton Cliffs, as far as a place where the projecting cliff is perpetually wave-washed, save for a short time at the lowest spring-tides. The name of this little headland is Kit Pape's Spot, and it will be readily recognised by a reference to Pl. XVII. It is marked on Sheet 128 of the Ordnance 6-inch map, dated 1854, and is here curiously figured as Kit Pape's Pot. Mistakes in place-names are not infrequent

* Mr. Lamplugh says that the walk from Sanwick to the "Contortions" is even harder; but that we have not attempted.

on this coast. At the point mentioned several strong springs of fresh water gush from the base of the cliff in a line of vertical fracture, the actual outflow of water being probably determined by the presence of the yellow marl-bands which are found in the base of the zone of *Rhynchonella cuvieri*. It is well to go to the extreme end of the section, because 50 yards west of Kit Pape's Spot we see some 10 ft. of flintless chalk forming the foot of the cliff, with several yellow marl-bands at the base, overlain by flinty chalk, and in turn overlying the top of the zone of *Holaster subglobosus*. We could not trace the "black band" at this situation, nor could any fossils be found, as the cliff is covered by seaweed. It is useful, however, to note these beds, because they are brought up by the vertical fault, the position of which is indicated on Pl. XVII.

Returning westward over Fall A (Pl. XVII) we see a fine and accessible section, the details of which are given in Pl. XVIII. To in any way interpret this exposure we must note the position of the vertical fault (Pl. XVII), and compare the position of the beds on the east and west side of it. The displacement is but small, as the throw is about 4ft. south; but it suffices to bring up the zone of *Rhynchonella cuvieri* on the east side, which is entirely missing on the west side.

Examining the face of the cliff (Pl. XVIII), the eye is at once attracted by a marked horizontal fissure containing a thin band of black shale, which is regarded as the Yorkshire equivalent of the *Actinocamax plenus*-marls, and is locally known as the "black band." This is the section described by Mr. Dakyns* as exhibiting an apparent unconformity. The "black band" is not at present seen on the east side of the vertical fault, and it will be noticed that, whereas we can follow it down to the beach, almost up to the west side of the fault, the displacement on the east side is not sufficient to bring it into view, and we only see several of the yellow marl-bands which are found in the base of the narrow zone of *Rhynchonella cuvieri*. It is important to notice that the sides of the vertical fault are marked by horizontal striæ, running S. 20 E., according to Mr. Lamplugh.

If we now compare the direction of the striæ on the beautifully polished surfaces of the horizontal fissure containing the "black band," we notice that they also run S. 20 E. The "black band," a little west of the point shewn in Pl. XVIII, is 1 to 8 inches thick, and is a pure black shale; but in the position here delineated it is replaced by a mass of crush-breccia, re-cemented by calcite, stained black by the colouring matter of the shale, and varying from 6 to 12 inches in thickness.

* J. R. Dakyns. Mem. Geol. Surv., "Country around Driffield." (Sheet 94 N.W.) p. 10, fig. 2. See also G. W. Lamplugh. "La Géologie de l'est du Yorkshire." Compte rendu du Congrès Géologique Internationale, Londres, 1888, p. 154. Mr. Lamplugh in this paper points out that this feature is due to a horizontal displacement of the flinty chalk, and not to an unconformity.

Zone of Rhynchonella cuvieri.

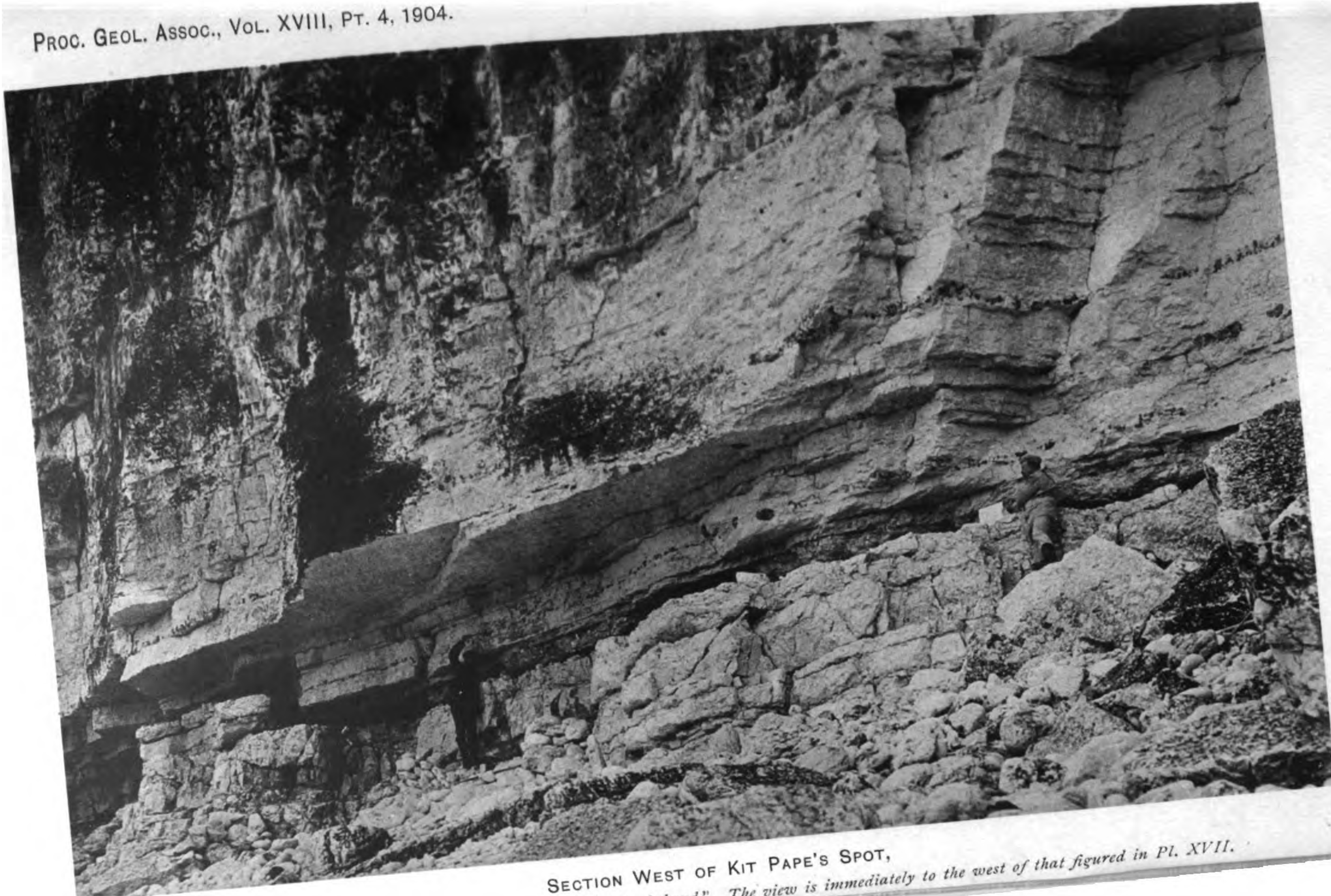
To form any idea of the physical conditions which determined this apparent unconformity we must examine the three beds which enter into it. On the east side of the vertical fault we notice that the base of the cliff is formed by an intensely hard cream-coloured rock, seamed by several marl-bands, especially at its base. This rock is flintless, rough with fragments of *Inoceramus mytiloides*, and is exposed for about 7 ft. 6 in. On the western edge of Fall A the same bed is seen, and is then rapidly covered up by fallen chalk. We have only the length of a few feet of this bed to work, and that badly exposed, but we collected from it

Inoceramus mytiloides .	3
Inoceramus lamarcki .	1
Rhynchonella cuvieri .	3
Terebratula semiglobosa	2

One of the examples of *Inoceramus mytiloides* was large and well-preserved, and this we brought away as evidence of a hitherto undescribed section of the *Rhynchonella cuvieri*-zone. We say "hitherto undescribed section" because Dr. Barrois placed his zone of *Actinocamax plenus* and *Inoceramus labiatus* (= *Rhynchonella cuvieri*)* well down in the pink beds of the zone of *Holaster subglobosus*, and Mr. William Hill's section† was taken near Nanny Goat's House. Above this cream-coloured rock of the *Rhynchonella cuvieri*-zone is the white chalk of that of *Terebratulina gracilis*, seamed with nodular flint-lines, and containing a characteristic fauna. As the *Rhynchonella cuvieri*-zone is incompletely exposed in its lower part we cannot expect to see the grey beds of *Holaster subglobosus* at this point, east of the vertical fault. Mr. Lamplugh is of opinion that he has seen the "black band" at the base of the cliff east of the fault, though it is now hidden by talus.

The zone of *Rhynchonella cuvieri* does not appear in the area covered by Pl. XVIII, but is seen rising in the cliff a little west of that point, and is readily accessible at a spot depicted in Pl. XIX, situated some fifty yards west of that seen in Pl. XVIII. By climbing up Fall B it can be worked *in situ*, and it will at once be obvious that we here have again the normal succession, for it lies between the "black band" and the first flint-line of the *Terebratulina gracilis*-zone, and is here 11 ft. 4 in. thick. At this situation (Pl. XIX) the "black band" has split into two layers. The lowest yellow marly band of the *Rhynchonella cuvieri*-zone is indicated by the top of the measuring-rod. The base of the cliff is cut in the zone of *Holaster subglobosus*. West of this point it is rare

* *Op. cit.*, pp. 194, 195.
† W. Hill, "On the Lower Beds of the Upper Cretaceous Series in Lincolnshire and Yorkshire," *Quart. Journ. Geol. Soc.*, vol. xliv, p. 336.



SECTION WEST OF KIT PAPE'S SPOT,

... of the "black band." The view is immediately to the west of that figured in Pl. XVII.

that we have any chance of reaching the *Rhynchonella cuvieri*-zone, as it rises out of reach in the cliff, though it can be traced here and there where the grass slopes are disconnected.

It can, therefore, be demonstrated that both east of the vertical fault (Pl. XVII), and at the situation of Pl. XIX, we have the normal succession of beds, from the zone of *Holaster subglobosus* to that of *Terebratulina gracilis*, and that it is only in the area covered by Pl. XVIII that the apparent unconformity exists.

Pl. XVIII shows the eastern part of the area between these two sections, wherein we cannot trace the zone of *Rhynchonella cuvieri*. Its only representative is in some fragments of cream-coloured rock in the crush-breccia of the horizontal fissure. These fragments contain no determinable remains of *Inoceramus mytiloides*.

Below the horizontal fissure (Pl. XVIII) is the zone of *Holaster subglobosus*, the bedding-planes of which are clearly shown in the plate; but no photograph could convey an idea of the intensity of the crushing and alteration of this chalk. The rock is seamed with calcite, and slipped and fractured in all directions. It would seem to be a hopeless quest to attempt to get fossils from such a matrix, but we had the good fortune to obtain two undoubted examples of *Holaster subglobosus* from it, and thus to place the horizon of this chalk beyond any possibility of doubt.

Zone of Terebratulina gracilis.

Above the horizontal fissure (Pl. XVIII), containing the crush-breccia and the remains of the "black band," is a hard white chalk, quite unaltered, seamed with bands of nodular flints, and containing numerous, but broken, organic remains. Mr. Sherborn's hammer is resting on the lowest flint-line. We append a list of fossils collected at this spot:

Holaster planus . . .	8
Terebratulina gracilis . .	2
Terebratulina striata . .	3
Rhynchonella cuvieri . .	3
Terebratula semiglobosa .	7
Terebratula carnea . .	3
Inoceramus lamarcki . .	7
Inoceramus bronguiarti .	3

We searched this bed over and over again, and failed to find *Inoceramus mytiloides*. As it yielded *Terebratulina gracilis*, and as the narrow bed containing *Inoceramus mytiloides* has already been found both east and west of this particular section, it is

clear that the white flinty chalk above the "black band" must be referred to the *Terebratulina gracilis*-zone, and that the *Rhynchonella cuvieri*-zone is certainly missing at this particular place.

The appearance of apparent unconformity can only be explained, as Mr. Lamplugh pointed out, by the supposition of an overthrust fault—a horizontal movement of the hard white flinty chalk over the flintless beds below, crushing out the zone of *Rhynchonella cuvieri*. We searched for a second fault west of the section shown in Pl. XVIII, but failed to find it. It appears, therefore, that the movement died out westward.

We have alluded to the fact that the "black band" is regarded locally as the homologue of the *Actinocamax plenus*-marls.* This peculiar bed is found in several places in Yorkshire, and Mr. J. W. Stather refers to the Hull and Barnsley railway-cutting, and Melton Bottoms, as the two best sections. But nowhere in Yorkshire has *Actinocamax plenus* been found in it.

The thickness of the *Rhynchonella cuvieri*-zone, and the conditions of the beds above and below it are so strange in the section shown in Pl. XVIII that we have felt impelled to investigate an inland exposure where the "black band" is well displayed, and the *Rhynchonella cuvieri*-zone more accessible. The best section is found at Barton-on-Humber, in Lincolnshire. Here are three large quarries, and in the farthest pit, that of South Ferriby, we have a fine section of the *Holaster subglobosus*-zone, exhibiting an abundance of *Discoidea cylindrica*, capped by the "black band," here 1 ft. 6 in. to 2 ft. thick, and yielding *Actinocamax plenus**; and this again overlain by 18 ft. of yellow-grey, marly, flintless chalk, containing *Inoceramus mytiloides*; and the whole crowned by white flinty chalk yielding *Terebratulina gracilis*. The orthodox succession is here well shown, and the "black band" is clearly the normal development of the *Actinocamax plenus*-zone in this area; so that there is every reason to conclude that the "black band," as indicated in Pl. XVIII and XIX, is its Yorkshire equivalent.

It will be noticed that the thickness of the *Rhynchonella cuvieri*-zone at Barton (15 ft. to 18 ft.) is also unusually small, though greater than that on the Yorkshire coast. We record a list of fossils obtained in half-an-hour's collecting in this zone at South Ferriby quarry.

Echinoconus castanea .	. 3
Rhynchonella cuvieri .	. 9
Terebratula semiglobosa	. 6
Terebratula carnea .	. 1
Inoceramus mytiloides .	. 8

* See W. Hill, *op. cit.*

We are indebted to Mr. J. W. Stather, the President of the Hull Geological Society, for the negative of Pl. XX, and for the measurements of the beds. The position of the "black band" is admirably brought out in the photograph, and the flintless zone of *Rhynchonella cuvieri*, and the flinty chalk of *Terebratulina gracilis* displayed with equal clearness. Mr. Stather points out that it is only the central six inches of the *Actinocamax plenus*-marls which is really black.

Dr. Barrois* states that the top of Buckton Cliff is formed by the chalk without flints, which he assigns to the *Marsupites*-chalk, or chalk of Bridlington. In the first place the chalk at the top of the cliff is seamed with great tabular bands of grey flint, and secondly, the zone there exposed is that of *Holaster planus*, as we shall presently show (p. 204). The greyness of the flint merges these flint courses into the tint of the time-stained cliff, and renders them difficult to follow at a distance.

As we pass westward on our return journey we notice the fine exposures of the beautiful red-tinted beds of the Lower Chalk, and the scars of Red Chalk at low water, and we meet with several large Paramoudra on the shore, one of which is more than 4 ft. in diameter. It is possible that the latter have fallen from the upper part of the *Holaster planus*-zone, at which horizon we know them to occur at North Sea Landing (Pl. XXX, p. 209).

When we arrive at Crowe's Shoot we have the chance of ascending the cliff at that point, or of returning to Speeton by the shore. Regarding this feature in the cliff Mr. Lamplugh writes:† "There is a huge slip about midway in the Speeton range known as Crowe's Shoot. At this place a great slice of chalk 150 yards long has moved forward and downward for 50 ft. or 60 ft., but has there been arrested, and has remained without further change for over a generation. The cliff is here 425 ft. high. Between this place and Chatterthrow, near Thornwick, a distance of four miles, there is as a rule absolutely no possibility of descending to the shore except by means of ropes."

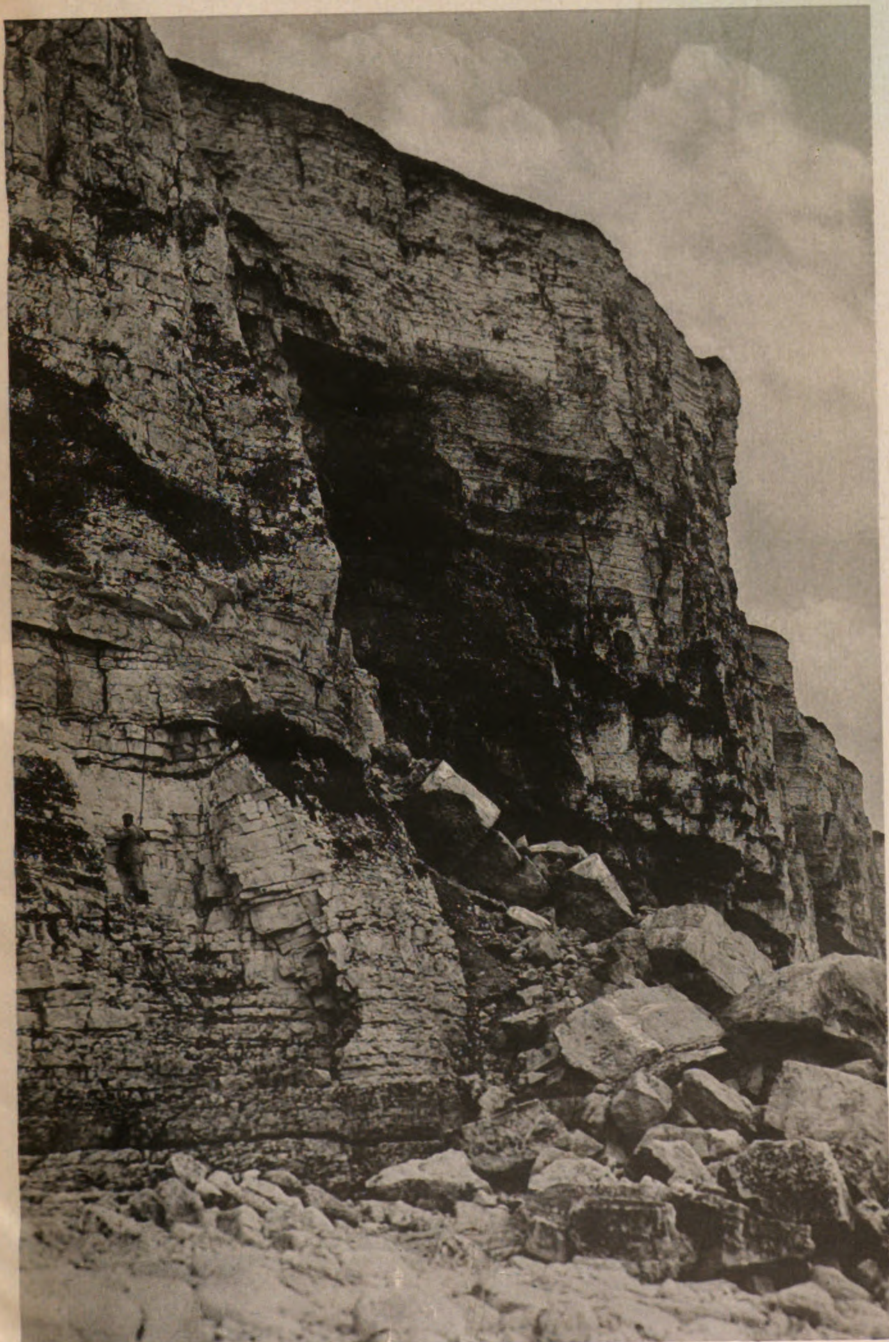
The ascent to Crowe's Shoot presents no difficulty, save that it is steep; and it is quite safe. It would be well, however, to have the guidance of someone who has made it before. Having scrambled up the chalk screes we reach the seaward front of the slipped face of cliff, and make for the fissure in the middle of it. Here we at once find *Terebratulina gracilis* and *Holaster planus*, together with a band of *Ostrea proboscidea*, the curious thick-shelled form which we shall note at North Sea Landing. A little higher up the slope, and to the east, we lose *Terebratulina gracilis*; so that we can here obtain a junction of the zones of

* C. Barrois. *Op. cit.*, p. 196.
† G. W. Lamplugh. "Notes on the White Chalk of Yorkshire." *Proc. York. Geol. and Polyt. Soc.*, vol. xiii, Part II, p. 175, 1896.

Terebratulina gracilis and *Holaster planus*. We can either round the eastern end of the slipped face, or pass through its centre by means of the fissure. Either way is equally easy and safe. We then find ourselves in a kind of ravine, the chalk on the seaward side being but a repetition of the actual cliff. We collect from such exposures as are clean enough, and obtain *Holaster planus* and *Echinocorys vulgaris*, but no examples of *Terebratulina gracilis*. The presence of *Echinocorys* is quite sufficient to exclude the existence of the *Terebratulina gracilis*-zone, and therein this horizon in Yorkshire conforms to our experience of the zone in southern sections. We thus establish beyond doubt the fact that the zone of *Holaster planus* crowns the cliffs at this point, and that the remainder of the flinty chalk below is in the zone of *Terebratulina gracilis*. By ascending the track in the Drifts we reach the cliff top.

We now take the cliff path to Speeton, passing Nanny Goat's House and Jackdaw's Crag on the way, and noting the configuration of the latter pinnacle, as it forms a useful guide when we are working on the chalk screes below. Following the edge of the cliff we come to a spot where the chalk cliffs end. Here we descend to the screes, working along their top as far as the west side of Jackdaw's Crag, and noting that the whole of these surfaces are in flinty chalk.

Ascending the steep slope shown in Pl. XXII, we collect *Terebratulina gracilis* and *Holaster planus* in fair numbers. They are here especially well seen below the strong grey flint tabular band, which we can trace in the cliffs towards Buckton. Above this tabular band we found no fossils, but we have no hesitation in assigning this surface to the zone of *Terebratulina gracilis*. Bluff 1 is obviously cut in this zone, and the same applies to the foundered Bluff 3, though neither yielded the name-fossil. The small slipped face marked 2 is in much better condition, and we there found twelve examples of *Terebratulina gracilis*. The masses of calcite in this surface were of great size, and one cavity in the chalk was barred-in by stalactites and stalagmites of this material. We call attention to the fact that Bluff 3 appears both in Plates XXI and XXII, and this is done so that the reader can form a continuous idea of the section, which embraces all the readily accessible exposures within this area. The remainder of the section shewn in Pl. XXIII merits a word of comment, as the question has arisen if it be in position. Looking at it from the shore there would appear to be no doubt that it is continuous with the cliff on the east; but viewing it from above, or from the low ridges of the Speeton clay, we feel more doubtful. Mr. Lamplugh is indeed of opinion that the portion of the cliff in question has foundered in pre-glacial times. Whatever has happened matters little from a zonal point of view, for the cliff is clearly in the zone of *Terebratulina gracilis*, though



VIEW 50 YARDS FURTHER WEST THAN PL. XVIII,

Shewing the normal zonal succession from Holaster subglobosus to Terebratulina gracilis. The "black band" is here split into three lines.

the name-fossil was not found at this particular point. We obtained *Holaster planus*, however, but no *Echinocorys*; so the unlikely contingency of a foundered cliff of *Holaster planus*-chalk is at once set aside. That we were unable to find *Terebratulina gracilis* is not remarkable, for the surfaces are in the last degree unfavourable, being grey with age, and covered with lichens. Anyone who takes the trouble to check these observations in the cliff-tops above the screes will readily appreciate our difficulties. It is a very nice place to hunt for calcite, cliff-spiders, and lichens, but we fancy that the fossil-collector will not be unduly tempted by its fascinations. We obtained the following fossils in the sections displayed in Plates XX and XXI.

Holaster planus, R.C.		*Rhynchonella cuvieri*, C.	
Hemiaster minimus	2	*Terebratula semiglobosa*, R.C.	
Cyphosoma radiatum	1	*Inoceramus brongniarti*, R.C.	
Salenia granulosa .	1	*Inoceramus lamarcki*, C.	
Cidaris hirudo .	1	*Ostrea vesicularis* . . .	1
Bourgueticrinus .	1	*Ptychodus* (small lateral tooth)	1
Terebratulina gracilis, R.C.			

Leaving the Speeton screes we now walk eastward along the top of the cliffs, noting such points of interest as occur on our way. A quarter of a mile south of the cliff, and half a mile north of Buckton Hall, is a small and badly exposed pit, with tabular flint-bands, but no fossils (Pit No. 3). This pit is probably in the base of the *Micraster cor-testudinarium*-zone. We have next to examine another small pit (No. 4) at the same distance from the cliff, and probably in the same zone. Our guide to it is the entrenchment which runs at right angles to the cliff, and comes to its edge at Barnet Shoot. A quarter of a mile south of Barnet Shoot we find this little excavation in the flinty chalk, which was being worked when we visited it in 1902. We found no fossils whatsoever, save a small Ammonite, about three inches in diameter, and very ill-preserved. The next point of interest which we reach is Kit Pape's Spot, mentioned on p. 198. Mr. Lamplugh gives the height of the cliff here as 325 ft. This point is approximately the western extremity of the Bempton Cliffs.

At Walmsley Siphon we note some yellow bands in the Chalk at the cliff-top, but could not reach the faces of the gully without a rope. Still farther east we reach Old Roll-up, where there appears to be a good exposure. Unfortunately, we had no rope with us, and could not investigate it. There is every reason to believe that the upper part of the cliff belongs to the zone of *Holaster planus*. We now reach Scale Nab, with its celebrated contortions. Much as we should have liked to have examined this wonderful feature from the shore, we had no opportunity

so to do. By the courtesy of the Council of the Yorkshire Geological and Polytechnic Society we are enabled to give a reduced photograph of Nos. 1 and 2 of their published series of plates of the contortions. Writing of this remarkable feature, Mr. Lamplugh says*: "The disturbance sets in suddenly a little to the left of the section seen in No. III,† and dies out as suddenly on the farther side of the Staple. For a space of about 200 yards the whole height of the cliff shows the strata plunging steeply this way and that in a series of sharp folds. Both eastward and westward of this place the beds lie quite regularly, with a very gentle dip southward. . . . Contortions are known to exist in the Chalk in many places in the interior, and a careful study of these in connection with those in the cliff-line would probably reveal the presence of definite zones of pressure and movement traversing the whole district." The whole of these contortions, save the extreme top, undoubtedly occur in the zone of *Terebratulina gracilis*. Violent as this disturbance is, its local effects seem to be singularly inconspicuous, for a consideration of the section (Pl. XXXVIII) between Speeton Station and Speeton Cliff shows no alteration in the regularity of the beds, and no variation in the dip. Passing over the site of the contortions on the cliff-top one notices nothing whatsoever to indicate their existence. Most of the pits in the Flamborough area show a dip of not more than 5° S.E., but that north of Buckton Hall, No. 3 of our series, gives a dip of about 10°. This was the only evidence which we could obtain of the local effect of the disturbance.

Two-thirds of a mile east of Scale Nab we cross the end of the Danes' Dike at a point called Cat Nab. A mile south of Cat Nab, and half a mile on either side of the Dike, are pits Nos. 7, 8, 9, 10, all in the zone of *Micraster cor-anguinum*. A mile farther east we pass Gull Nook. From Crowe's Shoot up to this point, and probably a little farther, perhaps as far as Close Nooks, the whole of the upper part of the cliff is cut in the zone of *Holaster planus*, while the remainder of the cliff is formed by the chalk of the zone of *Terebratulina gracilis*. The height of the cliff at Gull Nooks is 275 ft., being 50 ft. less than at Kit Pape's Spot; and by the time that we reach Chatterthrow the fall is so rapid that the cliffs measure only 125 ft.; and as the Chalk cliffs diminish, so do the Drifts which cap the Chalk thicken.

The walk along the top of these towering Bempton cliffs is full of interest; the bird-life and the methods of the cliff-climbers having an irresistible fascination for the stranger. We now reach the most beautiful spot on this wild and noble coast. From Barnet Shoot to Sanwick the cliffs are sheer and precipitous; but

* G. W. Lamplugh, *op. cit.*, p. 177.
† This is a reference to one of the plates in the paper quoted.

with a decrease in their altitude, and an increase in the Drifts, the coast-line is broken up into a series of supremely beautiful bays. The east side of Sanwick displays a grand series of parallel caves, all hollowed out along the master-joints of the chalk.

Great and Little Thornwick.

Chalk geology shows no finer example of buttressing and erosion by wave-action, and sculpturing by aerial agency, than is exemplified respectively by the rocks and Drifts of these bays.

As the cliff-section indicates (A), these bays, including Sanwick and Chatterthrow, can yield us nothing save the zone of *Terebratulina gracilis*. It is interesting to note that one can generally find rolled blocks of red-tinted chalk* on the beach at Great Thornwick, and Mr. Lamplugh tell us that after heavy storms the amount thrown up is considerable, suggesting that these beds may be exposed below low-water level, and so confirming our general observations as to the age of the chalk in the cliff. Pl. XXV admirably brings out the contrast between the massive ramparts of Bempton and the low drift-crowned ledges of Thornwick, and Pl. XXVII beautifully illustrates the sculpturing of rock and Drifts. Looking westward towards the Bempton cliffs at low tide one gains the impression that the base of the Bempton cliffs are easy of access from Thornwick. The deep caves at Sandwick, however, effectively bar the passage even at the lowest tides.

The chalk at Thornwick is intensely hard, and in the lowest beds the flints are nodular, becoming tabular in the higher levels. The flint is grey in colour, and not so abundant as in the two zones immediately above.

Zone of Terebratulina gracilis.

Dr. Barrois† does not assign a zone to these bays, and quotes but one fossil, namely, *Inoceramus brongniarti.* This is alone sufficient to stamp this section as one of remarkable difficulty, for Dr. Barrois has a perfect genius for finding fossils in the most unpromising exposures. Our own collecting amounts to only 16 species, but it demonstrates beyond all doubt that the horizon is that of *Terebratulina gracilis*. We append our meagre list of fossils, giving the number found, so that their frequency in occurrence may be appreciated.

* Some of this material is Red Chalk and some red-tinted chalk. The latter is found in the zone of *Holaster subglobosus*, and it is this to which we refer above.

† *Op. cit.*, p. 196.

FOSSILS FROM ZONE OF TERERRATULINA GRACILIS.

Holaster planus. .	C.	*Rhynchonella reedensis*	1
Holaster placenta .	3	*Terebratula semiglobosa*	7
Hemiaster minimus .	2	*Terebratula carnea* .	2
Bourgueticrinus .	2	*Inoceramus cuvieri* .	C.
Asteroidea . .	3	*Inoceramus lamarcki* .	C.
Terebratulina gracilis	45	*Inoceramus brongniarti*,	R.C.
Terebratulina striata	2	*Ostrea vesicularis* .	2
Rhynchonella cuvieri	7	*Porosphæra globularis*	3

The really common fossil here is *Inoceramus*, one example of *Inoceramus cuvieri* measuring 2 ft. across. *Holaster planus* is equally common, and quite as abundant as in its own zone; and so as to effectively separate this zone from that of *Holaster planus*, we call attention to the fact that *Echinocorys vulgaris* was not found at Thornwick. *Terebratulina gracilis*, considering the obdurate nature of this matrix, and the fact that it is always preserved as a crumbling iron-oxide pseudomorph, is reasonably easy to obtain. *Terebratula semiglobosa*, as in all other sections of this zone on the coast, is of large size. *Rhynchonella reedensis* was found at the highest level of this zone to which we could get access, and *Ostrea vesicularis* was of characteristic size and shape. As in all the sections north of Flamborough Head, the fossils found at Thornwick are in a deplorable state of preservation. They are valuable for zonal purposes, but, as specimens, are more fit for road-metal than for a place in a museum.

It will be noticed that in the summary of measurements (p. 277) we give an estimated thickness for this zone of 210 ft. Large though this measurement undoubtedly is, it would seem to be warranted by a consideration of the coast between Crowe's Shoot and Thornwick. Indeed, from Kit Pape's Spot to beyond Thornwick the whole of the lower part of this cliff, a distance of three miles, is cut in this zone. At Crowe's Shoot the cliff measures 325 ft., and the top and bottom beds belong respectively to the zone of *Holaster planus* and the Cenomanian series, leaving thus a very considerable depth of flinty chalk to be assigned to the zone in question. The zone of *Rhynchonella cuvieri* is of such insignificant thickness (11 ft.) that we can practically leave it out of our calculation. To anyone who tries to roughly apportion the zones at this point it will, we think, seem not unreasonable to allot a full 200 ft. for the *gracilis*-beds.

North Sea Landing and Holmes' Gut.

Another quarter of a mile brings us to North Sea Landing, with its famous caves on the east side. Pl. XXVIII gives a good

idea of the shape of the bay. This is an important fishing centre, and the sight when the boats come in, and have landed their catch, is one of varied and vigorous activity. As in Thornwick, the area available for collecting is but small, all the sides of the bay being covered with seaweed. The chalk is still remarkably hard, and the flints are grey and arranged in tabular bands, some of them being over 1ft. in thickness. The chalk is crystalline and infiltrated by calcite, masses of which at the head of the bay, on the east side, are of a rich yellow colour. Above the highest of the thick tabular flint-bands some yellowish bands of chalk are seen, and it was probably their presence which suggested to Dr. Barrois that the highest beds in the bay were cut in the zone of *Micraster cor-testudinarium.* Indeed, the same idea occurred to us; but careful collecting disclosed no evidence of a fauna belonging to that zone.

Pl. XXX shows a fine Paramoudra *in situ*, more than 3 ft. in diameter, with one of the massive tabular flint bands above it, over 1 ft. thick. When we take a boat from this point to Breil Head we notice six other Paramoudras, all in the upper part of the zone of *Holaster planus.* As they form a definite line here, and as we have met with them nowhere else, save among the fallen blocks from Speeton Cliff, it is probable that they form a useful guide to horizon on this coast. We would suggest that Yorkshire geologists should look out for them in quarries, and ascertain if the fossils associated with them belong to the *Holaster planus*-zone.

In a paper on the flints of the Chalk of Yorkshire, published in the Proceedings of the Geologists' Association, Vol. v, No. 61, Mr. R. Mortimer gives some interesting notes of these Paramoudras. We have only found them *in situ* in the upper portion of the *Holaster planus*-zone at North Sea Landing, but Mr. Mortimer records several which he found in the chalk scars which form the floor of this bay, one of which was no less than 5½ ft. in diameter. The same observer counted between this point and Speeton "in the cliff and on the beach, not fewer than 30 specimens, whole or in fragments." He also mentions the interesting fact that he found an example "in a pit at the Painsthorpe Wold, near the N.W. margin of the Chalk," and in a recent interview Mr. J. R. Mortimer states that he remembered another specimen in a pit at Thixendale. It will be interesting to see if further examples can be found in these quarries, and to ascertain if the fossils associated with them belong to the zone of *Holaster planus.*

Zone of Holaster planus.

Dr. Barrois, p. 196, refers this bay to zone of *Holaster planus*, and gives a list of eight species. Our list extends to 30 species, and

we entirely agree with the author of the *Recherches* in placing this bay in the same zone. Holmes' Gut, a western diverticulum of the main bay, which conveys a little stream to the shore, is also in the same zone, and yielded a small but characteristic fauna. We append our brief list of fossils obtained from this locality.

FOSSILS FROM THE ZONE OF HOLASTER PLANUS.

Holaster planus	30	*Ostrea vesicularis*	3	Approximate thickness 125 ft.
Holaster placenta	3	*Inoceramus cuvieri*	10	
Echinocorys vulgaris	10	*Inoceramus brongniarti*	4	
Pentacrinus	12	*Inoceramus lamarcki*	5	
Bourgueticrinus	8	*Spondylus dutempleanus*	1	
Asteroidea	12	*Plicatula sigillina*	4	
Terebratula semiglobosa	8	*Serpula fluctuata*	1	
Terebratula carnea	3	*Serpula*, sp.	1	
Terebratulina striata	5	*Parasmilia centralis*	1	
Rhynchonella plicatilis	1	*Melicertites semiclausa*	1	
Rhynchonella reedensis	1	*Melicertites globulosa*	3	
Rhynchonella cuvieri	15	*Ventriculites impressus*	1	
Crania egnabergensis	2	*Porosphæra globularis*	3	
Kingena lima	1	*Porosphæra pileolus*	1	
Ostrea hippopodium	2			
Ostrea proboscidea (a band)				

There are some interesting points in this list needing comment, but the reader is referred to the Zoological Summary for these. As we have remarked on p. 208, *Holaster planus* is as common in Yorkshire in the zone of *Terebratulina gracilis* as at its own horizon. Therefore, its presence, even in quantity, would not of necessity imply the existence of the *Holaster planus*-zone; but the association with it of *Echinocorys vulgaris* places the question of zone beyond doubt, for neither in Yorkshire, nor in the South of England, have we ever found *Echinocorys* below the level of the *Holaster-planus* zone.

To look for Chalk Rock on this iron-bound coast would seem to be rather a bootless quest. And such, indeed, it proved to be, for we could find no evidence of its existence either in a lithological or zoological sense. The chalk of this zone is hardly at all nodular, and is free from the customary yellow bands, and grains of glauconite and phosphatic nodules are entirely wanting.

It will be noted that *Terebratulina gracilis* does not figure in our list for the *Holaster planus*-zone at North Sea Landing. We regard its absence as important, for our previous experience

always leads us to expect its presence sporadically in the base of this zone.* The fact that special research failed to reveal it, therefore, would go some way to indicate that the base of the zone is not exposed in North Sea Landing, but is to be found between this bay and Thornwick. This observation gives point to our rather large estimate for the thickness of this zone, for we could hardly expect to obtain a thickness of 125 ft. between the western side of North Sea Landing and Newcombe. It is possible, of course, that the fossil exists in the western horn of North Sea Landing, where the chalk is covered by a dense mantle of seaweed, and in that case our estimate may be considered excessive.

We now leave this beautiful bay, and cross over the next headland to Newcombe, for it is here that we should expect to find the zone of *Micraster cor-testudinarium* at the top of the cliff.

NEWCOMBE.

Newcombe is a deep gash in the cliff, with an apology for a path running obliquely down its western face to a projecting ledge near the bottom. The lowest 20 feet can only be negotiated by means of a rope. The path itself is of a very uninviting nature, and we failed to descend more than one-third of the distance. Mr. Lamplugh, however, who is an expert cliff-climber, had no such scruples, and several of the best specimens were obtained by him.

The rock is not suggestive of the zone of *Micraster cor-testudinarium*; but in Yorkshire we do not expect to find much similarity to southern lithological characteristics.

Zone of Micraster cor-testudinarium.

This section does not give one much scope for collecting, but we are able to give the following little list of fossils.

Echinocorys vulgaris	2
Cardiaster cotteaui	3
Holaster placenta	1
Asteroidea	1
Rhynchonella reedensis	1
Spondylus dutempleanus	1
Ostrea vesicularis	2
Serpula turbinella	3

It will be noticed that *Micraster* does not appear in the list, and that *Cardiaster cotteaui* occupies a prominent position.

* See Part III, Devon, pp. 5, 43.

Three examples of the elongated and depressed shape-variation, which we associate with this zone, were found, as well as other fragments.* There is probably a band of this urchin at this level. We made diligent search for *Holaster planus* here, but failed to find it; so that there is every reason to think that we have assigned the upper part of this cliff to the right horizon. Naturally, with so difficult an access to the section, it was impossible for us to obtain a junction between this zone and the one below it; but we should say that the upper two-fifths of the cliff may be assigned to the zone of *Micraster cor-testudinarium*.

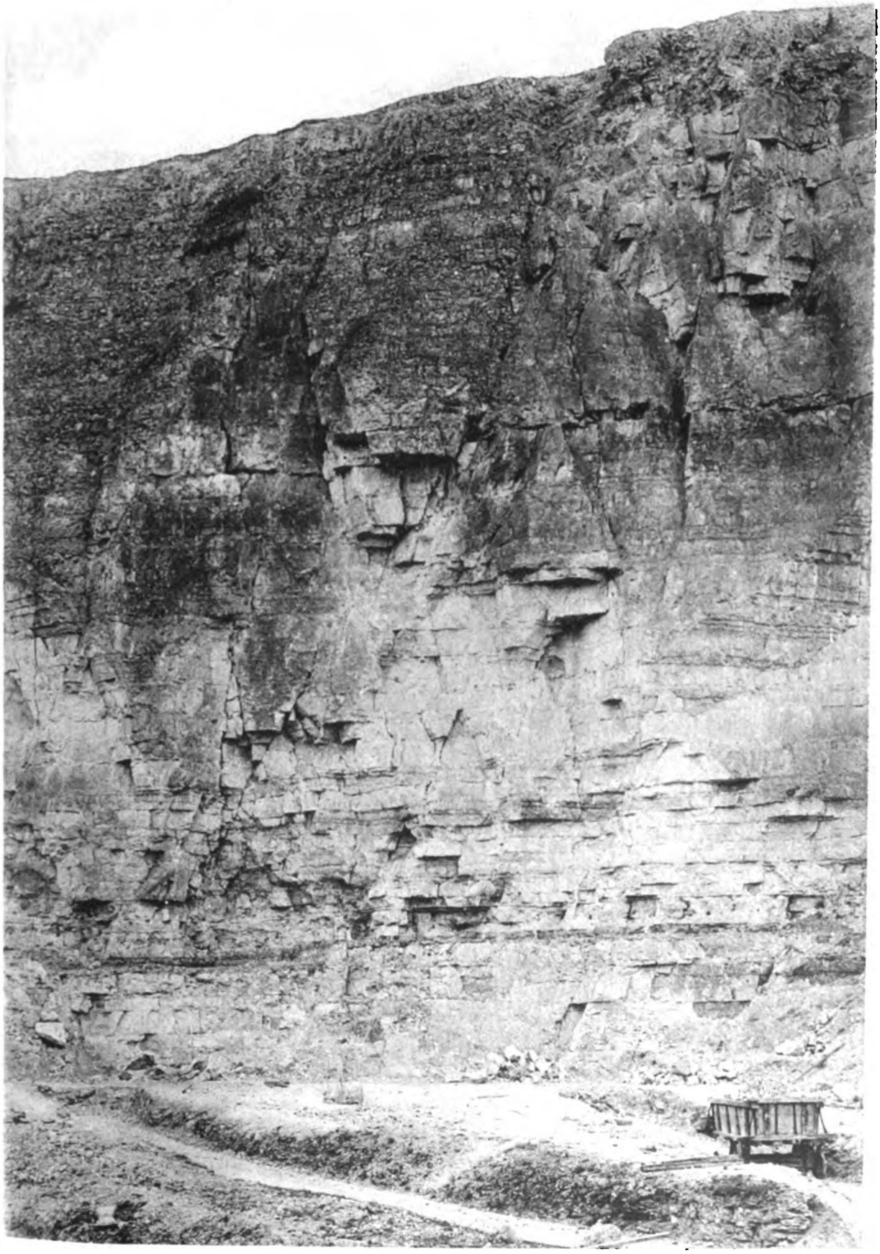
Dr. Barrois does not mention this little section. It should be noted that Newcombe lies mid-way between Cooness Nook and Carter Lane, and it must not be confounded with Newcombe Saddle, which is situated farther east.

Our next quest is to ascertain if there be any other accessible section in this zone between Newcombe and Selwicks. The dip of the beds indicates that the only likely spot is between Breil Point and Cradle Head. Unfortunately, the cliff is 150 ft. high here, and there is no means of access to the shore, save by boat, or by ropes from the cliff-top. There is a small and shallow bay between Petrel Hole and Fall Hole, and we choose this as the most promising locality. At low tide there is the usual beach of large chalk boulders, and the base of the cliff is, by rare good fortune, clear of seaweed. We accordingly enter into negotiations with the fishermen, and they agree to attempt a landing if the sea be dead calm. The rocks are so numerous that, even if there is the smallest sea on, the boat would be staved in. After waiting for a fortnight, we get a welcome telegram from Flamborough, and find that the sea is really smooth. Once outside North Sea Landing, however, it is clear that there is a distinct swell, and we begin to wonder if a landing can be effected. On arriving at the little bay, the men at first decline to land us, but after some search we find a scar which runs out into deep water at the western horn of the bay, and taking a flying leap from the boat, we manage to land.

Breil Head.

This is the name on the 6-inch Ordnance Map for the bay just mentioned, but the section which we examined apparently lies between Petrel Hole and Fall Hole. In any case, the exact locality can readily be fixed by reference to Pl. XXIX, which gives a good idea of the appearance of the bay. The chalk is here perhaps a shade less hard than in the sections already described, and the cliff is seamed with both grey flint tabular-bands and nodular flint-lines from base to top. There are also several marl-bands. The nodular nature of the rock, and the yellow

* See Part III, Devon, p. 43.



SOUTH FERRIBY QUARRY, BARTON-ON-HUMBER, LINCOLNSHIRE,
Shewing normal zonal succession.

Three examples of the elongated and depressed sh… which we associate with this zone, were found, as w… fragments.* There is probably a band of this urchin … We made diligent search for *Holaster planus* her… find it: so that there is every reason to think … assigned the upper part of this cliff to the … Naturally, with so difficult an access to the … impossible for us to obtain a junction between this … one below it; but we should say that the upper … the cliff may be assigned to the zone of *M…* *testudinarium*.

Dr. Barrois does not mention this little section. … be noted that Newcombe lies mid-way between C… and Carter Lane, and it must not be confounded with … Saddle, which is situated farther east.

Our next quest is to ascertain if there be any oth… section in this zone between Newcombe and Selwicks. … of the beds indicates that the only likely spot is … Point and Cradle Head. Unfortunately, the cliff … here, and there is no means of access to the shore … or by ropes from the cliff-top. There is a small and … between Petrel Hole and Fall Hole, and we … the most promising locality. At low tide there … beach of large chalk boulders, and the base of the … good fortune, clear of seaweed. We accordingly … negotiations with the fishermen, and they agree to … landing if the sea be dead calm. The rocks are … that, even if there is the smallest sea on, the boat … staved in. After waiting for a fortnight, we get a … telegram from Flamborough, and find that the sea … smooth. Once outside North Sea Landing, however … that there is a distinct swell, and we begin to wonder … can be effected. On arriving at the little bay, the … first decline to land us, but after some search we … which runs out into deep water at the western horn of … and taking a flying leap from the … we managed …

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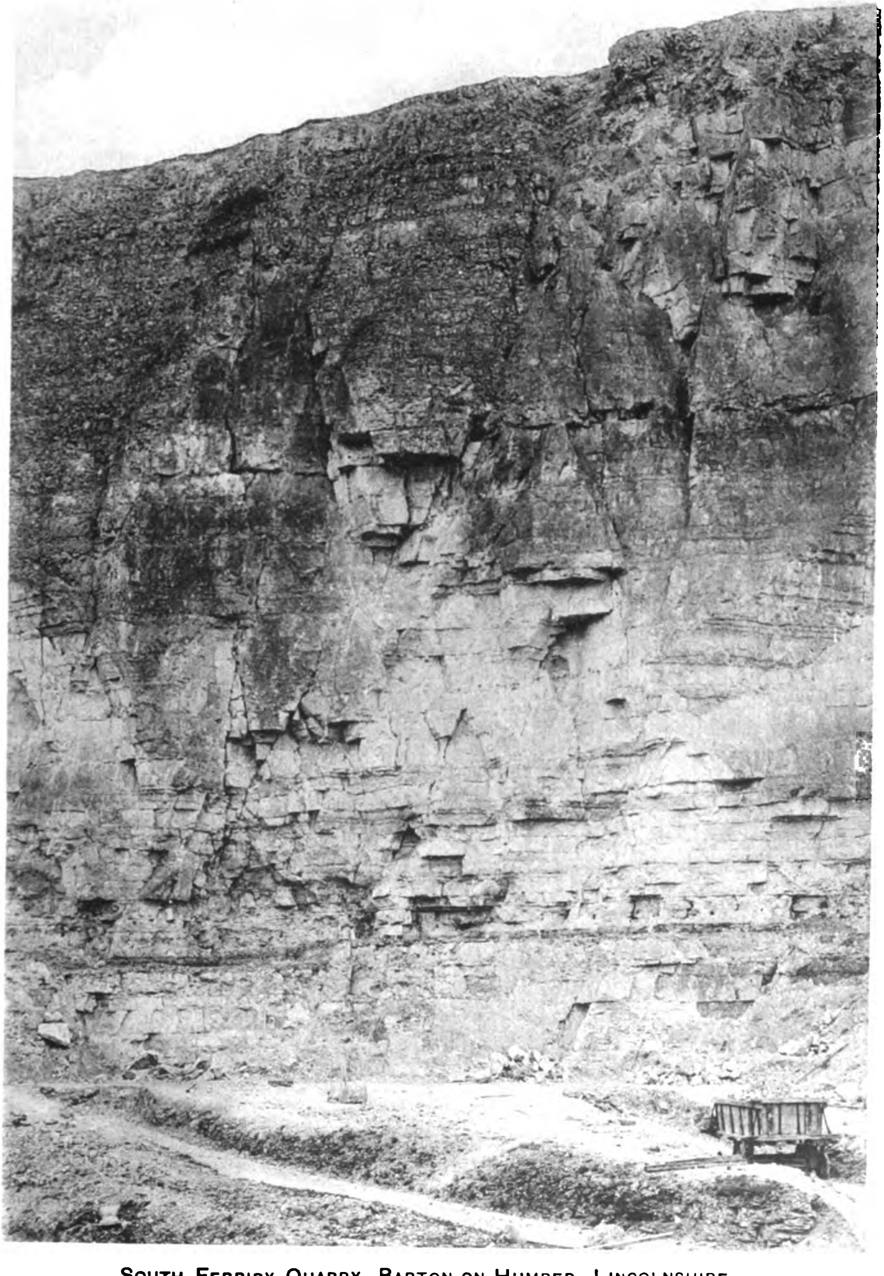
* See Part III. Devon, p. 4…



South Ferriby Quarry, Barton-on-Humber, Lincolnshire,

Shewing normal zonal succession.

nodular chalk-bands, so characteristic of this zone in the South, are here conspicuously wanting. Indeed, nobody passing in a boat would ever imagine that the *Micraster cor-testudinarium*-zone is here exposed.

The accuracy of our localisation of this zone was confirmed in an almost dramatic manner, for within thirty seconds of landing we found an example of *Micraster*. And now came the crucial point. What was this *Micraster*? We rapidly cleared an ambulacrum and a few millimètres of periplastronal area, and then our minds were set at rest, for it was *Micraster præcursor*, of the group-form found in the *Micraster cor-testudinarium*-zone, and at no other horizon whatsoever. We spent nearly two hours collecting in this bay, but could only find this scanty list of fossils.

FOSSILS FROM THE ZONE OF MICRASTER COR-TESTUDINARIUM AT BREIL HEAD.

Micraster præcursor {group-form of the *M. cor-testudinarium*-zone}	3
Echinocorys vulgaris	3
Holaster placenta	1
Infulaster rostratus	1
Cidaris subvesiculosa spine	1
Bourgueticrinus	1
Asteroidea	1
Crania egnabergensis	1
Terebratula semiglobosa	2
Spondylus latus	1
Inoceramus cuvieri	12
Ostrea vesicularis	1
Ostrea hippopodium	1
Plicatula sigillina	2
Porosphæra globularis	1
Porosphæra pileolus	1
Plocoscyphia convoluta	3
Ventriculites cribrosus	1

Our estimate of 120 ft. for the thickness of the *Micraster cor-testudinarium* zone is confessedly speculative. It is greater than the 113 ft. recorded for the coast of Dorset and the 109½ ft. measured in Sussex, but that in itself is no valid objection to its approximate correctness. Unfortunately, our inability to make the full descent of the path at Newcombe robbed us of the chance of obtaining a junction between the zone and that of *Holaster-planus*. We hope to do this with the aid of a rope on a future occasion. Meanwhile, we must be content to give such imperfect evidence as is available. The height of the cliff at Newcombe is about 125 ft. If our estimate of the upper two-fifths of this section for the *Micraster cor-testudinarium*-zone be

correct, it gives us 45 ft. for this bed. The distance from Newcombe to Cradle Head is nearly three-quarters of a mile, and it is in the bay between Breil Point and Cradle Head that the approximate junction between the zones of *Micraster cor-testudinarium* and *Micraster cor-anguinum* is displayed. Allowing for the dip of the beds, we think that it is not unreasonable to suppose that the specified 75 ft. for the former zone may be here obtained.

Whether *Micraster cor-testudinarium* will stand as the name-fossil for this zone in Yorkshire is more than doubtful. Save for three examples of the broad form, we have as yet seen only *Micraster præcursor* in the Yorkshire collections. On the coast even the latter form is so rare as to be useless as a name-fossil; but in inland sections, such as the Etton and Kirkella Cuttings, it is more abundant, though it apparently never reaches the numerical importance to which we are accustomed in the South. Further collecting in the coast and inland sections just mentioned may bring to light a fossil which is at once dominant and reliable as a local equivalent name-fossil. We have in this paper adhered to the old title for the zone, simply because as yet we know of none better.

The discovery of *Micraster* in this bay was particularly gratifying, because it had never been found on the coast before. One example of *Micraster præcursor* was found at the eastern end of this section, so it is fairly clear that the zone extends to, and even beyond, Fall Hole, as shown in the cliff-section (Pl. XXXVIII).

Infulaster rostratus is another notable accession to our list, and forms, so far as we know, a new record for this zone, both in Yorkshire and in all other English sections. We shall allude to the zonal range of this echinid in the Zoological Summary, for to us this vast extension of vertical range is as remarkable as it is unexpected.

We have now established two sections of the *Micraster cor-testudinarium*-zone on this coast, where none had been known before, and have fixed the horizon for that part of the Etton and Kirkella Cuttings, which yielded the examples of *Micraster præcursor* in the Mortimer Museum and in Mr. Stather's collection.

Dr. Barrois (p. 197) states that he did not work this portion of the cliff, but he says that "the zones of *Micraster cor-testudinarium* and *Micraster cor-anguinum* have not a great development in this region. They are formed of a hard flinty chalk, and are poor in fossils; they crop out near Breil Point, Cradle Head, and Stottle Bank Nook, but I was unable to examine them. Their thickness does not seem to me to be greater than 30 mètres." Though Dr. Barrois was right in his localisation of the former zone, he had less grounds for placing

the latter in this area, for he was not aware that the *Micraster cor-anguinum*-zone was in the main a flintless chalk, with flints in its lower portion alone. Accordingly, our combined measurement for these two zones exceeds his by over 250 ft.

That the Breil Head section had not been previously worked is probable from the remark of our octogenarian coxswain, who informed us that he had never heard of anybody having been landed there before. Mr. Lamplugh, whose knowledge of the coast is unrivalled, was also definite on this point.

Continuing our survey eastwards, we note that at Gallows Hole, which forms the western side of Cradle Head, the tabular flint-bands extend for three-quarters of the way up the cliff, and that the top of the cliff is cut in flintless chalk. We are now, therefore, as we shall presently show, in the zone of *Micraster cor-anguinum*. At Stottle Bank Nook only the base of the cliff, for about 20 ft., is in the flinty chalk, and we shall demonstrate later that the whole of the cliff at this point is in the zone of *Micraster cor-anguinum* (p. 234).

The cliff now faces due east, and nearly half-a-mile south of Stottle Bank Nook we reach the beautiful bay of Selwicks, which the ingenuity of the cartographer has turned into Silex, chiefly for the reason, apparently, that the larger portion of the bay exhibits nothing but flintless chalk.

SELWICKS BAY.

This bay is mainly due to the weakening of the strata caused by the fault, which has already been described by Mr. Lamplugh,* who says: "Flints are seen on the southern side of the Head, just where the cliffs begin to be so cave-worn and fissured, in a recess known as High Stacks. They are here present in the scar nearly to the base of the cliff; but the chalk has a pretty constant rise northward, and they soon rise in the cliff foot, and by the time we have gained the point where the sea always washes the base of the cliff, and thus bars further advance, which is only a few hundred yards farther north, the chalk contains flints nearly to the top of the cliff, which is here about 90 ft. in height, excluding the drifts. . . . Upon examining the south side of this bay (Selwicks), the cliff is again seen to have flints from top to bottom, occurring in irregular patches, which form inconstant layers. Thence they may be traced to the centre of the bay, when the beds become suddenly contorted and shattered, and dip down at a constantly increasing angle, until they are almost vertical. Here all the interstices of the shaken chalk are filled with veins of calc-spar. In the cliff the actual fault is concealed by a great mass of slipped drift. . . . On

* G. W. Lamplugh, "On a Fault in the Chalk of Flamborough Head," *Proc. Yorkshire Geol. and Polytech. Soc.*, vol. vii, Part III, p. 242, 1880.

the beach, however, the actual line of fault can be distinctly traced at low water. On examining the evenly bedded chalk on the north side of the slip, the existence of the fault is immediately proved; for there are no flints whatever in the cliff. Neither do they reappear until we reach the grand group of arches and passages, which, projecting seaward, form the northern side of Selwicks, where a few flints may be seen in the rocky pavement, under circumstances resembling those under which they first appear at High Stacks, viz., for a short distance they occur sparingly, but soon increase in abundance on the beach, and again take their place in the cliff in force. Reckoning from the data thus supplied, I should estimate the amount of downthrow to the north at about 80 ft. As seen on the beach the direction of the fault is N.E. and S.W."

When we were going over the ground together, in the autumn of 1902, Mr. Lamplugh stated that he was now convinced that he had over-estimated the amount of the downthrow.

The masses of calcite in the lines of crush are remarkable in their magnitude, and we have measured one vein which was over 3 ft. thick. Doubtless, owing to the fault, the chalk in this bay is harder than that at Breil Head. Fossils are very scarce.

Dr. Barrois states (p. 197) that the contact of the zones of *Micraster cor-anguinum* and *Marsupites testudinarius* is visible in Selwicks, and he records *Offaster corculum* [*Cardiaster pillula*] in the upper beds of flintless chalk in that bay. He then goes on to say that "the white, soft, flintless chalk, which appears at Flamborough Head, extends without a break to Bridlington. This is the zone of *Marsupites;* it is here displayed with the same lithological character as in the Isle of Thanet, and with the same palæontological characters as in the rest of England."

Now it is quite clear that Dr. Barrois thought that the *Micraster cor-anguinum*-zone must necessarily be in flinty chalk, as in the rest of England, and that for this reason he placed only the flinty beds in this bay in the zone in question. He definitely states, moreover, that the flintless chalk belongs to the zone of *Marsupites testudinarius*, that it extends as far as Bridlington, and he quotes the existence of *Cardiaster pillula* in the highest chalk of Selwicks in support of his view.

We shall show that there are three zones between Selwicks and Bridlington—those of *Micraster cor-anguinum*, *Marsupites testudinarius*, and *Actinocamax quadratus;* that *Cardiaster pillula* is one of the rarest fossils on this coast, rigidly confined to the zone of *Actinocamax quadratus* at Sewerby Cliff; and that what Dr. Barrois took to be *Cardiaster pillula* were the cross-sections of *Infulaster rostratus*, the commonest fossil in the *Micraster cor-anguinum*-zone of Yorkshire. We shall return to these questions in greater detail when we consider the three

SPEETON CLIFFS AND SCREES. 4. JACKDAW'S CRAG. 5. NANNYGOAT'S HOUSE.

zones on the south side of Flamborough Head. The fossils found in Selwicks Bay are as follows:

Infulaster rostratus .	10	*Rhynchonella reedensis*	2
Echinocorys vulgaris .	5	*Crania egnabergensis* .	1
Cidaris sceptrifera .	4	*Ostrea vesicularis* .	1
Asteroidea . .	3	*Vincularia disparilis* .	2
Actinocamax granulatus,	2	*Porosphæra globularis*	5
Terebratula semiglobosa,	1	*Porosphæra pileolus* .	3

We shall give the full fauna of this zone when we deal with the section south of Flamborough Head. Fair collecting may be had at Common Hole, which can be worked from the top even at high tide.

We now leave Selwicks and cross the Headland to High Stacks, at which point there is an easy path to the shore.

High Stacks to Beacon Hill.

It will be well at this point to define the actual limits of the *Micraster cor-anguinum*-zone, both north and south of the Headland. A reference to the Cliff-section (Pl. XXXVIII) will show that we fix its base approximately at a well-marked line of holes, which have weathered out in the surface of the cliff. This line can be traced from Breil Point to Cradle Head, and sinks to the shore near Stottle Bank Nook, as indicated on Pl. XXIX. The last line of flints is seen at the north side of Selwicks and at Kindle Scar, and this is the same line as that which appears at High Stacks, the repetition of this feature being due to the Selwicks' fault. We are thus confronted with the remarkable fact that this zone is based in flinty chalk, while the larger part is in chalk devoid of flint—a condition without parallel in the rest of England, so far as our experience goes. We trace this zone on the south side of Flamborough Head as far as Beacon Hill, S.W. of South Sea Landing, to a spot where we see a 3-ft. cube of diorite on the white chalk scars. (See Pl. XXXV.)

As the whole of the chalk on the south side of Flamborough Head is readily accessible, we have an opportunity for taking accurate measurements. We fix the top of the *Micraster cor-anguinum*-zone at the first plate of *Uintacrinus*, and from this point to South Sea Landing we measure 56 ft. 6 in. We found that our measurements from Cliff End, Sewerby, to South Sea Landing so closely coincided with those published by Mr. Lamplugh* that we were content to take his measurements for the remainder, as we were pressed for time, and considered that we could more profitably utilise the remainder of our brief holiday in extending our knowledge of the fauna. Mr. Lamplugh

* G. W. Lamplugh. *Op. cit.* Appendix to Part I, pp. 80-84.

shows* that the level of the cliffs alters but little from South Sea Landing to High Stacks, for the reason that the line of strike very nearly coincides with the cliff line, so that we get only 105 ft. in the two miles between these two points. From the High Stacks to Common Hole, on the south side of Selwicks, he measured 76 ft. We must probably add 24 ft. to allow for the height of the cliff at Stottle Bank Nook, so that the total measurement for this zone works out as follows:—

Flintless Chalk.	From South Sea Landing to the diorite cube under Beacon Hill	56.6
	From High Stacks to South Sea Landing . .	105.0
Flinty Chalk.	From Common Hole to High Stacks . . .	76.0
	Remainder of Cliff at Stottle Bank Nook . .	24.0
	Total thickness of the *Micraster cor-anguinum*-zone =	261.6

Dr. Barrois (p. 197) gives a list of fossils collected be-between High Stacks and South Sea Landing, and among them we note *Belemnitella merceyi* (= *Actinocamax granulatus*), *Inoceramus lingua*, *Marsupites ornatus*, and *Offaster corculum* (= *Cardiaster pillula*). We have already shown that he regards the whole of the flintless chalk as belonging to the zone of *Marsupites testudinarius*, and it follows that this particular section is naturally referred to the same horizon. It is probable that the presence in quantity of *Actinocamax granulatus*, a very rare fossil in the zone of *Micraster cor-anguinum*, and a characteristic one in the *Marsupites*-band of Margate and Brighton, misled him. We have indicated on p. 216 that Dr. Barrois mistook *Infulaster rostratus* for *Cardiaster pillula*. If the fracture takes place at right angles to the greatest diameter of the test, the section shown is circular, and resembles that of *Cardiaster pillula*; but a glance at the ornamentation should at once negative the determination of the latter urchin. This mistake explains his reference in the list to *Cardiaster pillula*. We confess that we can give no explanation for the presence of *Marsupites testudinarius* or *Inoceramus lingua*, save that they may possibly have been found on blocks which had been carried by the sea from Dane's Dike. Our own extended collecting has never revealed the former, save in its own limited band in the upper part of the *Marsupites* zone, 250 ft. higher in the chalk than the level of the flintless beds at High Stacks; and the latter we have not recorded lower than the middle of the *Marsupites*-band. It is easy to see how the mistake has been made, in the case of *Infulaster rostratus* and *Actinocamax granulatus*, but it is none the less unfortunate, in that it has vitiated the whole of his conclusions as to the age of the chalk from Selwicks to Bridlington.

The chalk is still very hard, though notably less so than

* *Op. cit.*, p. 69.

on the north side of Flamborough Head, and not a particle of flint is to be seen. There are many marl-bands, however, and all the partings along the bedding-planes are marked by fine suture-like junctions in which a thin layer of iron-stained marl can generally be detected. Marcasite crystals and nodules are common, and its presence in these higher zones of the White Chalk is quite new to our experience.

Zone of Micraster cor-anguinum.

(Local equivalent—Zone of Infulaster rostratus.)

Considering the comparative rarity of fossils, and their poor state of preservation, our lists for this zone are fairly large. It will at once be noticed that we have been compelled to make a new departure in the case of the name-fossil for this zone in Yorkshire, and the reason for such a course must be given fully, for we are well aware that it is in the last degree inadvisable to found a new zonal name without very cogent reasons. It will be seen that we have retained the usual zonal title, and this course has been adopted because we recognise the importance of keeping the nomenclature of the zones in the Yorkshire area on the same basis as those in the south of England. At the same time we feel that local conditions, especially when they are as paramount as in the present instance, must have their due value. *Micraster cor-anguinum* is one of the rarest urchins on this coast, for we have found but three fragments of it, and two more examples were yielded by the pits; whereas *Infulaster rostratus* is found in boundless profusion throughout the zone, and we have also recorded it in pits in the flinty chalk of the base of the zone. The latter is essentially the dominant fossil of this zone in Yorkshire, and to ignore its incomparable zonal value would be to shut our eyes to overwhelming evidence. We have already submitted our views as to the name-fossil of this zone in Yorkshire to Mr. Lamplugh, and we are glad to say that such a course has his unqualified approval. Indeed, the necessity for a departure from the ordinary routine forced itself upon him in 1898, when he read a paper, entitled "Some Open Questions in Yorkshire Geology," before the Hull Geological Society. His views will be found on p. 10 of this thoughtful and suggestive communication.

We again desire to emphasise the fact that we employ this new zonal title in its legitimate local sense, and for local use only.

The list of fossils from this zone is here appended, and we mark the frequency or infrequency of their occurrence by the usual symbols, and, when the fossils are rare, by indicating the actual number found.

FOSSILS FROM ZONE OF MICRASTER COR-ANGUINUM.

Micraster cor-anguinum fragments	3
Echinocorys vulgaris	RC.
Infulaster rostratus	C.
Cardiaster ananchytis	1
Cidaris sceptrifera	RC.
Cidaris subvesiculosa	8
Cidaris clavigera	1
Cyphosoma corollare	1
Bourgueticrinus	RC.
Asteroidea	C.
Kingena lima	4
Terebratula semiglobosa	RC.
Terebratula carnea	3
Terebratulina striata	10
Rhynchonella reedensis	6
Crania egnabergensis	6
Ostrea vesicularis	RR.
Ostrea wegmanniana	2
Plicatula sigillina	12
Inoceramus cuvieri	C.
Pecten cretosus	3
Spondylus latus	2
Lima sp. (cast)	2
Actinocamax granulatus	RC
Actinocamax verus	6
Ammonites (*leptophyllus*-group)	1
Ammonites sp.	1
Parasmilia centralis	28
Parasmilia granulata	1
Axogaster cretacea	1
Scalpellum maximum	2
Balanid	1
Bryozoa	10
Spinopora dixoni	1
Serpula planus	2
Serpula sp.	5
Serpula turbinella	12
Serpula granulata	2
Serpula ampullacea	1
Oxyrhina mantelli	1
Ventriculites radiatus	C.
Ventriculites cribrosus	RR.
Ventriculites decurrens	R.
Plocoscyphia convoluta	C.
Coscinopora infundibuliformis	RR.
Guettardia stellata	RC.
Leptophragma murchisoni	
Porosphæra globularis	C.
Porosphæra globularis var. *nuciformis*	2
Porosphæra pileolus	9
Porosphæra pileolus var. *patelliformis*	9
Porosphæra pileolus var. *arrecta*	1
Lituola nautiloidea	1

We are now nearing the area of the Flamborough Head sponges, for we find them sporadically throughout the zone. These so-called silicified sponges are, however, in a marked minority.

It will be remembered that we record *Actinocamax granulatus* at Selwicks. Two examples were found in the base of the flintless chalk, and the species continues in unbroken continuity throughout the zone. These belemnites are very difficult to remove from the chalk of this zone, as the matrix is so hard and adherent.

Echinocorys is not uncommon, but we did not succeed in obtaining a single uncrushed example. We are quite unable to say what the characteristic shape-variation of this zone may be in Yorkshire, and we thereby lose one of our best guides to horizon.

Infulaster rostratus is found so abundantly that anyone could readily collect several hundred examples. We brought away

SPEETON CLIFFS AND

60 examples for examination, but well-preserved tests are rare. We counted no less than nine specimens on a block of chalk two feet square.

Apart from the fact that we have to depend entirely on weathering for displaying a fossil, it is difficult to obtain anything in a satisfactory state of preservation, for brachiopods, lamellibranchs, corals, and even *Porosphæra*, are so permeated with iron-oxide as to be rendered almost useless for purposes of study.

I.—From Beacon Hill to One-Sixth of a Mile East of Dike's End.

II.—From One-Sixth of a Mile East of Dike's End to 635 Ft. West of the Footpath on the Western Side of Dike's End, Corresponding with the Position of the Four Seaweed-Covered Blocks on the Shore.

We have already mentioned (p. 217) that the big 3-ft. cube of diorite under Beacon Hill roughly marks the spot where the *Micraster cor-anguinum*-zone and the *Uintacrinus*-band have their junction. This erratic has been here for years, and is a notable object on the white scars, for it can be readily seen from the cliff-top opposite Sewerby House, 1½ miles to the westward. It is the only large erratic on the white scars between Dike's End and South Sea Landing, and it cannot possibly be mistaken. Its position is marked on Pl. XXXV.

Under Beacon Hill the bedding is nearly horizontal, so that *Uintacrinus* can be found occasionally at the foot of the cliff for about 100 yards east of the cube of diorite. An additional guide will be found in the existence of two thick marl-bands, 2 ft. 6 in. apart, which are seen in the lower part of the cliff behind the erratic. Seven feet below the lower marl-seam the first scattered band of *Uintacrinus* occurs. We trace this fossil westward up to a point one-sixth of a mile east of Dike's End. The exact bluff where the last *Uintacrinus* plate and the first scute of *Marsupites* were found is indicated on Pl. XXXV, and corresponds with the second letter *r* in "ordinary" on the 6-in. Ordnance Map, Sheet 128, date 1854. In this bluff is a marl-band on the eye-line, and the highest *Uintacrinus* plate was found 4 ft. 3 in. below it, and the lowest *Marsupites* plate 2 ft. above it. We adopt this marl-band at the approximate junction of the *Uintacrinus*-band and the *Marsupites*-band.

The little bluff where the junction of the two members of the *Marsupites*-zone takes place forms the eastern horn of a shallow bay, the western limit of which is seen on Pl. XXXVI, at a spot where four large seaweed-covered blocks lie on the shore in the

shape of an irregular parallelogram, the wide side of which faces Flamborough Head. Three of the blocks are of calcrete*, and one of diorite, and their position is indicated on Pl. XXXVI. A few yards to the westward of these four blocks is a 3-in. marl-band, which falls to the shore at this point, and the position of which is indicated on the same key-plate. We collect *Marsupites* plates to a level 15 ft. 6 in. below this marl band, the plates becoming notably rarer in the last twenty feet, although the best and more complete tests were found just below the latter level.

The measurements of the *Marsupites*-zone work out as follows:—

	ft.	in.
From the highest *Marsupites* plate, 15 ft. 6 in. below the 3-in. marl-band near the four seaweed-covered blocks, to the end of the compact chalk on the west side of Dike's End	42	6
Contorted chalk on the west side of Dike's End to the compact chalk	22	0
From the east side of Dike's End to the lowest *Marsupites* plate in the bluff one-sixth of a mile east of Dike's End	56	1
From the lowest *Uintacrinus* plate, 7 ft. below the lower of the two marl-bands, 2 ft. 6 in. apart (by the diorite cube) to the highest *Uintacrinus* plate in the bluff one-sixth of a mile east of Dike's End . . .	87	5
	208	0

Therefore, *Marsupites*-band	=	120 ft. 7 in.
Uintacrinus-band	=	87 ft. 5 in.
Total thickness of *Marsupites* zone	=	208 ft.

This zone extends for a distance of one mile along the coast, being equally divided into *Marsupites*-band and *Uintacrinus*-band; but as the former sub-zone is situated in rapidly rising beds, and the part of it east of Dike's End is very poorly exposed, this division of the zone does not afford good scope for collecting. Much of the cliff is obscured by rainwash from the overlying drifts, and that portion east of Dike's End is largely hidden by grass and earth. Alluding to the latter section Mr. Lamplugh† mentions that Mr. J. W. Stather found a single example of *Marsupites* on the east side of the ravine. Our own collecting demonstrated that scutes of this crinoid were fairly common in this situation, and we found an almost complete test not far from the junction with the *Uintacrinus*-band.

The nature of this chalk is somewhat different from that allotted to the *Micraster cor-anguinum*-zone, being softer and having more numerous marl-bands. Like the latter zone it is an entirely flintless chalk. The interstratification is very irregular, thick blocky bands and thin platy layers following each other without any definite order. Marcasite crystals are present, but are less common than in the zone below.

* G. W. Lamplugh, *Geol. Mag.*, Dec. IV, vol. ix, p. 575. † *Op. cit.*, p. 69.

Zone of Marsupites Testudinarius.

The division of this zone into the *Marsupites*-band above, and the *Uintacrinus* band below, is as obvious and necessary here as in the South of England. Indeed, we know of no section where the remains of this crinoid are more abundant, though the hardness of the rock give few opportunities for obtaining well preserved specimens. How *Uintacrinus* has remained undiscovered on this coast is a mystery, for east and west of Hartendale Gutter (Pl. XXXV) the rock is in parts literally rough with plates and ossicles, though connected plates are very rare. Mr. Lamplugh noticed these plates long before the publication of his paper in 1895,* but determined them as ossicles of an asteroid. *Actinocamax granulatus* is fairly common in both divisions of the zone, but *Antinocamax verus*, so abundant in the *Uintacrinus*-band at Margate, and found also at the same horizon at Brighton and Salisbury, is here quite rare, though existing in both bands. *Ammonites leptophyllus* was not found, nor have the Yorkshire geologists ever found it here; and *Terebratulina rowei* and the nipple-shaped head of *Bourgueticrinus* are also missing. *Zeuglopleurus rowei*, however, is found at the base of the *Marsupites*-band and the top of the *Uintacrinus*-band, thus establishing a second record of occurrence of this interesting and rare echinid at this horizon. *Echinocorys vulgaris* is almost rare in the *Marsupites*-band, except at the top, where there is a scattered line of these urchins. It is common, however, in the *Uintacrinus*-band, though there is no bed of it at the junction of the two zoological divisions of the zone, as in Thanet. *Micraster* has not yet been found in this zone. The Flamborough Head sponges are found in considerable abundance, increasing in number and variety as we ascend in the beds. The following fossils were collected in the two divisions of this zone.

FOSSILS FROM MARSUPITES-ZONE.

Marsupites-band.		*Uintacrinus*-band.	
Marsupites testudinarius	C.	*Uintacrinus*	C.
Uintacrinus (at base only)	R.	*Echinocorys vulgaris*	R.C.
Echinocorys vulgaris	R.R.	*Infulaster rostratus*	2
Infulaster rostratus	2	*Zeuglopleurus rowei*	2
Cardiaster ananchytis	1	*Salenia granulosa*	1
Zeuglopleurus rowei	1	*Cidaris sceptrifera*	R.C.
Cidaris sceptrifera	R.C.	*Cidaris hirudo*	R.C.
Cidaris hirudo	R.C.	*Cidaris subvesiculosa*	R.C.
Cidaris subvesiculosa	R.C.	*Bourgueticrinus*	R.R.
Bourgueticrinus	R.R.	*Ophiura*	1
Asteroidea	R.C.	Asteroidea	R.R.

* *Op. cit.*, p. 82.

FOSSILS FROM MARSUPITES-ZONE (*continued*).

Marsupites-band.

Crania egnabergensis .	1
Rhynchonella reedensis .	R.C.
Terebratulina striata .	2
Kingena lima . .	4
Terebratula semiglobosa.	1
Actinocamax granulatus	R.C.
Actinocamax verus .	1
Ostrea vesicularis .	R.C.
Ostrea wegmanniana .	R.C.
Spondylus latus . .	3
Inoceramus cuvieri .	R.C.
Inoceramus lingua .	3
Plicatula sigillina .	5
Notidanus microdon .	1
Serpula granulata .	1
Ventriculites radiatus .	C.
Ventriculites cribrosus .	R.C.
Ventriculites flexuosus .	R.
Plocoscyphia convoluta .	C.
Coscinopora infundibulformis . . .	R.C.
Guettardia stellata .	R.R.
Leptophragma murchisoni,	R.R.
Heterostinia obliqua .	R.C.
Siphonia königi . .	R.R.
Porosphæra globularis .	C.
Porosphæra globularis var. *nuciformis* .	3
Porosphæra pileolus .	8

Uintacrinus-band.

Crania egnabergensis .	1
Rhychonella reedensis .	R.C.
Terebratulina striata .	4
Kingena lima . .	2
Thecidea . . .	1
Actinocamax granulatus	R.C.
Actinocamax verus .	1
Ostrea vesicularis .	R.C.
Ostrea wegmanniana .	R.
Spondylus latus . .	1
Spondylus dutempleanus	1
Lima hoperi. . .	1
Inoceramus cuvieri .	R.C.
Plicatula sigillina .	5
Lamna appendiculata .	1
Serpula ilium . .	2
Serpula fluctuata . .	1
Serpula granulata .	1
Parasmilia centralis .	2
Parasmilia fittoni. .	1
Parasmilia cylindrica .	1
Ventriculites radiatus .	C.
Ventriculites cribosus .	R.C.
Plocoscyphia convoluta .	C.
Coscinopora infundibuliformis . . .	R.C.
Guettardia stellata .	R.
Heterostinia obliqua .	R.C.
Porosphæra globularis .	C.
Porosphæra globularis var. *nuciformis* . .	4
Porosphæra pileolus .	2
Porosphæra pileolus var. *patelliformis* . .	10

The calcite sponges of Flamborough Head are intentionally omitted from the list as it is impossible in the present state of our knowledge to make such a record sufficiently exact to be of any zonal value.

FROM THE FOUR SEAWEED-COVERED BLOCKS ON THE SHORE, 635 FT. WEST OF THE PATH AT DIKE'S END, PL. XXXVI, TO CLIFF END, SEWERBY.

There is a mile of this, the *Actinocamax quadratus*-zone, the richest and most easily worked chalk in Yorkshire. It is the bed which has for so many years been famous for its sponges, and deserves to be still more famous for the rest of its supremely interesting fauna.

The chalk is hard, white, and splintery, with many marl-partings and crystals and nodules of marcasite. The smaller bedding-planes are marked by the curious suture-partings of iron-stained marl, common to all the beds in this area. The amount of marl here reaches its maximum, both in the finer bedding-planes and as marl-bands. It may be mentioned that the quantity of marl steadily increases as we ascend the zones, just as the hardness of the rock decreases.

The *Actinocamax quadratus*-zone is proverbially variable in the abundance of its fossils, being at its best splendidly rich, and at its worst the epitome of barrenness. Even at its richest this zone in Yorkshire affords but indifferent collecting, and the barren acres are so completely worthy of the name that at times it is quite a relief to find even *Porosphæra* to relieve the dead monotony. Still, by persistent search a perfectly satisfying fauna can be obtained, though it is in many respects an unusual one, and as far as we know, peculiar in England to the Yorkshire area.

The measurements are taken from the highest *Marsupites* plate, 15 ft. 6 in., below the 3-inch marl-band, near the four seaweed-covered blocks on the shore, to the end of the chalk at Cliff End, Sewerby. The total thickness of the *Actinocamax quadratus*-zone as exposed on this coast is 177 ft.

Zone of Actinocamax quadratus.

(Local equivalent—Zone of Inoceramus lingua)

Yet again have we tentatively to suggest a local equivalent, instead of the customary general title for this zone. Indeed, it would be difficult to do otherwise, however loyal we may be to old names, for the simple and sufficient reason that *Actinocamax quadratus* has yet to be found in this area in Yorkshire. As we shall shew, when dealing separately with the belemnites, none of the local collections contain a single example of the true *Actinocamax quadratus*. We have 177 ft. of this zone exposed on the coast, and the inland pits give us probably another 150 ft., but we get nothing which cannot be called merely a high development of *Actinocamax granulatus*.

Again, we should naturally fall back on *Cardiaster pillula* as an alternative name-fossil, but we are confronted with the fact that this is one of the rarest fossils in the zone. Indeed, Mr. J. W. Stather, whose patient work on this coast merits all praise, has never found it in the Sewerby Cliffs, and we only collected six examples on the coast and seven in pits.

As an instance of care and exactitude in collecting, Mr. Stather's methods are worthy of comment, for they afford an example for other workers in difficult and unknown areas. Mr. Stather numbered all the beds in Mr. Lamplugh's Appendix (*op. cit.* Part I), and has localised each fossil by a reference to the actual band in which it occurred. Though he, in common with other local collectors, was unable to define the zones, with the exception of the *Marsupites*-band, the occurrence of each fossil is preserved in such a precise manner that the evidence is capable of being used with absolute certainty.

Of the other common irregular echinids *Echinocorys vulgaris* is too consistently crushed to allow one to rely on it for zonal shape-variations; and *Cardiaster ananchytis*, though found in abundance, is not characteristic of the *quadratus*-chalk in the South of England, but rather of that of *Belemnitella mucronata*. *Hamites* and *Scaphites binodosus*, though perfectly distinctive of this horizon in Yorkshire, are too restricted in their levels, and too rare, to be of any service. They occur in bands, and especially in the case of *Scaphites*, then only above the 150 ft. level.

Sponges, which are so abundant and so characteristic, are not readily available for this purpose, in that so large a number of them are still unnamed, and our knowledge of the vertical range of some of the species is still so imperfect.

We have, therefore, to fall back on *Inoceramus lingua* as the most likely organism for a local name-fossil. It is very rare below the base of the zone, as we may judge from the fact that we record three examples only, and these from the top of the *Marsupites*-band. We have found it abundantly in the Sewerby Cliffs, and it is generally to be found in the quarries which occupy a higher horizon than the coast-section. Therefore, until we discover a better local name-fossil, we propose to adhere to *Inoceramus lingua* for this purpose. It has one other advantage, in that it is so essentially local that it is found nowhere else in England; and the fact that it is common at the same horizon in North Germany renders it additionally acceptable for the position of index-fossil.

We shall deal at length with the fauna of this zone in the Zoological Summary (p. 259), and we now append the list of fossils, together with an indication of their frequency of occurrence.

FOSSILS FROM THE ZONE OF ACTINOCAMAX QUADRATUS.

Cardiaster pillula	6	*Actinocamax granulatus*	RC.
Cardiaster ananchytis	C.	*Actinocamax verus*	4
Echinocorys vulgaris	RC.	*Ammonites*	2
Infulaster rostratus	8	*Nautilus*	2
Micraster (Bessingby only)	R.	*Scaphites binodosus*	RR.
Cidaris hirudo	C.	*Scaphites inflatus*	R.
Cidaris sceptrifera	5	*Scaphites* sp.	R.
Cidaris subvesiculosa	2	*Hamites*	R.
Cyphosoma corollare	4	*Aptychus* (Bessingby)	1
Bourgueticrinus	12	*Cœlosmilia laxa*	2
Asteroidea	C.	*Axogaster cretacea*	3
Rhynchonella reedensis	C.	*Pleurotomaria*	1
Rhynchonella limbata	1	*Scalpellum maximum*	1
Terebratula semiglobosa	6	*Serpula turbinella*	2
Terebratulina striata	5	*Serpula ampullacea*	1
Kingena lima	8	*Cristellaria rotulata*	1
Crania egnabergensis	6	*Frondicularia*	1
Inoceramus lingua	C.	*Ventriculites radiatus*	C.
Inoceramus cf. *undulatus* (Mant.)	1	*Ventriculites cribrosus*	RC.
Inoceramus cuvieri	C.	*Ventriculites impressus*	R.
Inoceramus sp.	2	*Ventriculites infundibuliformis*	C.
Ostrea vesicularis	C.	*Ventriculites flexuosus*	R.
Ostrea wegmanniana	C.	*Plocoscyphia convoluta*	C.
Plicatula sigillina	C.	*Porochonia simplex*	RC.
Spondylus latus	2	*Coscinopora infundibuliformis*	RC.
Spondylus dutempleanus	1	*Guettardia stellata*	RC.
Lima hoperi	1	*Leptophragma murchisoni*	R.
Lima granosa?	1	*Cœloptychium agaricoides*	R.
Pecten cretosus	5	*Heterostinia obliqua*	RC.
Avicula	5	*Siphonia königi*	RC.
Mosasauroid vertebræ	2	*Cliona cretacea*	C.
Lamna appendiculata	1		

The Calcite sponges are intentionally omitted from this list, but in the Zoological Summary (p. 263) will be found all those mentioned by Dr. Hinde in the British Museum Catalogue, 1883.

Lithological Summary.

We have met with rock as hard as the Yorkshire Chalk on the coasts of Dorset and the Isle of Wight, but that has been in vertical chalk. Never in our experience have we seen so much marl in the White Chalk, in the shape both of marl-bands, and

in fine suture-like partings parallel with the bedding-planes. We have submitted rock showing these suture-partings to Dr. Flett, Dr. Kitchin, and Mr. Howe. The structure somewhat suggests cone-in-cone. Microscopic sections show nothing which throws any light on the condition. Mr. Howe suggests that the suture-partings may be due to differential movements occurring in the mass, especially so far as the simpler sutures are concerned. When the contact surfaces have separated and have weathered out the appearance of a honeycomb structure is exhibited. Mr. Howe does not think that this formation is incompatible with the same idea, though it perhaps suggests a structure due to shrinkage, that is, a sort of rough structure quite comparable with cone-in-cone. These suture-partings are found in every zone on this coast. Pl. XXXVII shows a very moderate degree of this suture-parting in the *gracilis*-chalk of Thornwick. It is much more developed in the higher zones.

As we have already mentioned, the beds get less hard as we ascend the zones, the progressive decrease of hardness being temporarily arrested by the action of the fault in Selwick's Bay. The marl, on the contrary, increases in amount as we ascend the zones.

Roughly speaking, Flamborough Head divides the flinty chalk on the north from the flintless chalk on the south. The junction of the flinty and flintless chalk is indicated approximately by a line drawn from Stottle Bank Nook through pits 10, 9, 8, 7, 6, then passing between Buckton Hall and pits 3 and 4, and finally curving to the S.W., through Hill Ends, which lies to the north of Speeton Station. A reference on the map (Pl. XL) will enable the reader to follow this line with ease.*

The *Rhynchonella cuvieri*-zone is the only bed on the north side of the headland which contains no flint. Throughout this area the flints are greyish in colour, and for this reason, when the cliffs are high, the flint-bands are very difficult to distinguish from below. The flints begin in the base of the *Terebratulina gracilis*-zone as nodular lines, but they soon become tabular in the main. As we near the summit of the flinty chalk the flints die out, just as they came in, as scattered nodular lines. The actual point at which they disappear is 100 ft. above the base of the zone of *Micraster cor-anguinum*, at the little promontory known as High Stacks. In the intermediate zones the tabular-bands predominate, reaching their maximum in the *Holaster planus*-zone, where they sometimes are as much as a foot in thickness.

* See also Lamplugh's Sketch Map, *Proc. York. Geol. and Polyt. Soc.*, Vol. xiii, p. 173. 1896.

SPEETON CLIFFS AND SCREES.

Zone of Rhynchonella cuvieri.

We have only examined one exposure of this zone in our area, and that the one west of Kit Pape's Spot, described on p. 200. As it only averages about 10 ft. in thickness, it is hardly likely that we should be able to define therein a band equivalent to the Melbourn Rock. Beyond the fact that it is here a hard cream-coloured rock, seamed throughout with yellow marl-bands, there is nothing to add to what we have already written. This bed is greatly compacted by pressure, but on the south side of the Humber, at South Ferriby Pit, it is less condensed, and is there the most marly chalk of this zone which we have ever seen.

Zone of Terebratulina gracilis.

Flints first appear as lines of scattered nodules at the base of this zone. The chalk is massive, compact, intensely hard, and white, and contains but little marl. Some of the masses of calcite in this zone are enormous. On the shore under the Buckton Cliffs we often see blocks of this material measuring one or two feet across. We have noted the stalactites and stalagmites of yellow calcite in the Speeton Cliffs on p. 204. In our experience the yellow calcite on the coast is confined to the zones of *Terebratulina gracilis* and *Holaster planus*.

Zone of Holaster planus.

Tabular bands of grey flint reach a great development in this zone, some of them being over a foot in thickness. The chalk is much the same in appearance as in the *Terebratulina gracilis*-zone, with the exception that there are a few yellowish bands in the upper part of this zone slightly suggestive of the yellow bands of nodular chalk in southern counties. Here, however, the bands are not nodular. At this horizon calcite is again a prominent feature, some of it in the upper part of the zone at North Sea Landing being of a bright sulphur-yellow colour.

Zone of Micraster cor-testudinarium.

The chalk is here still massive, but rather less hard than in the zone below, and marl-bands are becoming commoner, and the flint-bands less tabular. Though there are a few faint yellow bands in this zone, none of them are nodular, and nobody examining the section at Breil Head would for a moment imagine that the beds belonged to the zone in question.

Zone of Micraster cor-anguinum.

As we have already shown, the first 100 ft. of this zone is cut in flinty chalk, the flints being mostly in tabular bands at the

base, then becoming both tabular and nodular higher up, and finally dying out again as nodular courses. The chalk is massive at the base of the zone, but is interspersed with flaggy layers in the upper beds. Marl-bands now become a definite feature at this horizon, and crystals and nodules of Marcasite are very common and reach their greatest development. In nearly all instances we notice that the mass of crystals lies in a cavity in the chalk, sometimes one of considerable size. Prof. H. E. Armstrong's explanation of the cavity is that the sulphur of the pyrites is oxidised, and that calcium sulphate is formed, which, being much more soluble than chalk, is washed out. The cavity is probably little more than the hole occupied by the pyrites—larger to the extent of the chalk carried away by the action of the acid. What remains is a pseudomorph in iron rust.

Zone of Marsupites testudinarius.

This zone is entirely devoid of flint, not even a single isolated nodule being seen. Only in the *Uintacrinus*-band is the chalk at all massive, for irregular alternations of blocky and flaggy chalk, interspersed with marl-bands, are the rule. The lack of homogeneity in the composition of the beds is well brought out in the cliffs on the east side of Dike's End (Pl. XXXV). This is due to the alternations of compact beds with marly and flaggy bands, thus affording uneven resistance to atmospheric weathering. At a distance the effect is like that seen in the Lias or in the zone of *Holaster subglobosus*. Marcasite crystals and nodules are abundant.

Dr. Barrois evidently regards the *Marsupites*-zone as being generally a flintless chalk. As far as our experience goes it is so in Yorkshire alone. Even in Thanet it contains the "Bedwell-line," and scattered nodules of flints occur sporadically. In the Salisbury area also a few irregular bands of nodular flint are found, and we know that in Dorset and Sussex flint courses are abundant. We have evidence that the denuded *Marsupites*-zone of Devon must have contained flints from the flint cast of one of the plates of those crinoids found at White Cliff,* and in the flints of the Haldon Hills.† According to Mr. C. Griffith, this zone is flinty both in Hampshire and in the Isle of Wight.

Hearing from Mr. Lamplugh that Mr. Mortimer had found plates of *Marsupites* near Fimber in *flinty* chalk, we wrote to the latter and received the following reply: "I have two separate plates of *Marsupites*, found in separate places in the flinty chalk, both from near Fimber." This statement would indicate that the zonal divisions of the flinty and flintless chalk may differ inland from those which we have described on the coast. We

* A. W. Rowe, Part III, Devon, *Proc. Geol. Assoc.*, vol. xviii, p. 3.
† A. J. Jukes Brown, *Geol. Mag.*, Oct., 1902, p. 449.

make no further comment as we have no personal knowledge of this locality. We have, however, made inquiries from Mr. Stather, who has no knowledge of the occurrence of *Marsupites* in flinty chalk from this neighbourhood, and whose experience in other inland sections is that this crinoid is always found in flintless chalk, as on the coast.

Zone of Actinocamax quadratus.

The description given for the *Marsupites*-zone would apply with equal propriety to this chalk, with the exception that the marl-bands are here even thicker and more numerous. In this zone, and in the one below it, the rock is sensibly softer, but it is never anything but hard, according to our southern ideas of the higher beds of the Chalk. In some of the inland pits, notably No. 28, which are at a higher level than the beds on the coast, the chalk is intensely hard and much more massive. In the pits where the massive chalk is found they quarry the rock for building purposes, and on the whole it resists the weather surprisingly well. Marcasite is less common than in the two zones immediately below. In our experience this is the only section of the *Actinocamax quadratus*-zone which is devoid of flint. In all other English sections which we have seen flint lines are quite common, and according to Mr. C. Griffith the same condition obtains in Hampshire and in the Isle of Wight. It is always a marly chalk.

Chalk Pits in the Flamborough Head Area.

In an area like the one under discussion chalk-pits are of peculiar interest and importance, particularly as the Chalk in inland Yorkshire has the reputation of presenting difficulties practically beyond the power of solution. In our opinion these difficulties have been greatly exaggerated. Indeed, too much stress has been laid on the supposed difficulty in zoning pits, not only in this county, but in the south of England. With time, patience, and a working knowledge of the fauna sufficiently good to enable one to determine fossils from fragments, very few pits are incapable of being readily and accurately zoned.

Thirty-two pits are marked on the map (Pl. XL), and in addition we examined seven others outside this particular area, making thirty-nine in all. Of these we had no difficulty in zoning thirty-five. Those in which we failed to find any zonal fossils were as follows:

No. 3 (369). Small pit in flinty chalk, half-a-mile N.E. of Buckton Hall, overgrown with grass and lichens. No fossils found.

No. 4 (331). Small pit in flinty chalk, one-third of a mile S. of Barnet Shoot. No zonal fossil found.

No. 6 (320). Small pit one-third of a mile S.E. Bempton Grange. Almost grassed over, and only layers of platy chalk with a few scattered flints shewing. No fossils found.

(330). This pit is ploughed-out, and is not numbered on the map. Chalk shewing on the field, but no flints. *Ostrea vesicularis* the only fossil found.

It must be remembered that we were working with a map dated 1854, and that not a few pits marked on that sheet (No. 128) have been ploughed-out or completely obliterated by grass. Possibly other pits have been opened since that date of which we have no knowledge. There were several pits in the *Actinocamax quadratus*-area which we could have readily added to our list, as Mr. Lamplugh and Mr. Stather had obtained characteristic fossils from them; but as we did not have time to examine them ourselves, they have not been numbered on the map. In all instances we give geographical indications, so that our observations may be checked, and our lists extended; and in each case we put the figures of the contour-lines by the side of the number of the pit, together with the indication of the zone in brackets. It must be understood that we did not attempt to make exhaustive lists from these pits, but only to zone them as rapidly as possible.

When we mention that two pits were assigned to the zone of *Terebratulina gracilis* by the presence of its name-fossil, here represented by disorganised iron-oxide pseudomorphs; that five were allotted to the *Micraster cor-anguinum*-zone by the occurrence of the small, fragile, and fragmentary *Infulaster rostratus;* and that the age of the solitary pit in the *Uintacrinus*-band was established by the discovery of the small and inconspicuous plates of this crinoid, we consider that we have done much to prove our point that, even in the barren and inhospitable chalk of inland Yorkshire, the smallest and most unobtrusive zonal fossils may be found, if sufficient time and patience be expended on the search.

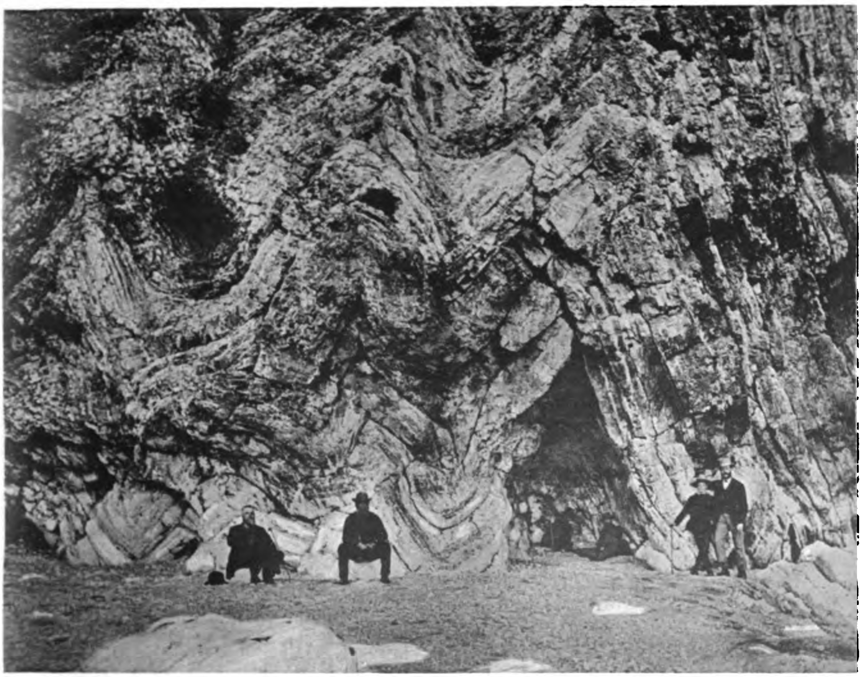
With the exception of No. 3, where the dip is about 10°, all the other pits show a gentle inclination of about 5°, or even less. We could trace no evidence of the Scale Nab disturbance, unless the increased dip in No. 3 be an instance in point.

So far as we can judge from our necessarily limited survey of this portion of the country, the highest beds of this basin are found near Ruston Parva, the northern edge of the basin running along the coast-line from Speeton to Thornwick.

We now take the numbered pits *seriatim*, very briefly

West Side of Thornwick Bay, Looking Towards

Scale Nab and the Famous Contortions.



Detail of the Contortions.

describing each one, and stating the zoological evidence on which we rely for establishing the zone in each instance.

No. 1 (350). [T. g.] A small pit in flinty chalk at Reighton in the zone of *Terebratulina gracilis*. In it we found the name-fossil of this zone and *Inoceramus lamarcki*.

No. 2 (300). [T. g.] A small double pit in flinty chalk at Reighton, in the zone of *Terebratulina gracilis*. The name-fossil was not found, but we found *Holaster planus*, *Inoceramus brongniarti*, *Rhynchonella cuvieri*, and one example of *Kingena lima*. The latter is our first record of this brachiopod for this zone in any English section. Exposure poor, and chalk grey with age.

No. 3 (369). [M. ct.] A very small pit in flinty chalk half-a-mile N.E. of Buckton Hall. Chalk grey with age, and covered with grass and lichens. We found no fossils whatever, but consider that the pit is in the zone of *Micraster cor-testudinarium*.

No. 4 (331). [M. ct.] A small pit with recently worked surface in flinty chalk, one-third of a mile south of Barnet Shoot. With the exception of fragments of *Inoceramus*, and a small and much worn Ammonite, we found no fossils. We consider that this pit is in the zone of *Micraster cor-testudinarium*. The position of the pit is so important that we examined it several times, but on each occasion with a negative result.

No. 5 (300). [M. ca.] A small and badly exposed pit in flintless chalk one-sixth of a mile north of Speeton Station. It yielded *Infulaster rostratus*, and is without hesitation assigned to the zone of *Micraster cor-anguinum*. This small pit is in flintless chalk.

No. 6 (320). [M. ca.] A very small pit almost overgrown with grass. Only some platy layers of chalk, with a few scattered flints. No fossils were found, but we place it at the level of 100 ft. from the base of the zone of *Micraster cor-anguinum*. The pit is one-third of a mile south-east of Bempton Grange (See paragraph following No. 10).

No. 7 (250). [M. ca.] A fair-sized pit on the east side of Stone Pit Lane, showing a few nodular flint lines, and therefore at the same horizon as No. 6. It yielded *Infulaster rostratus*, *Echinocorys vulgaris*, *Inoceramus cuvieri*, *Terebratula semiglobosa*, and *Porosphæra globularis*.

No. 8 (250). [M. ca.] Pit of moderate size with grey flint tabular bands, one-sixth of a mile south-west of Sixpenny Hill. It yielded a portion of *Micraster cor-anguinum*, *Infulaster rostratus*, *Cidaris sceptrifera*, *Bourgueticrinus*, *Terebratula semiglobosa*, *Ostrea vesicularis*, *Inoceramus cuvieri*, and *Serpula turbinella*.

No. 9 (214). [M. ca.] A small pit 300 yards south of No. 8, also with grey tabular flint bands, yielded *Infulaster rostratus*, *Bourgueticrinus*, *Rhynchonella reedensis*, and *Inoceramus cuvieri*.

No. 10 (200). [M. ca.] This is a pit of medium size immediately S. of Sixpenny Hill Plantation, and contains grey tabular bands of flint. In it we found *Micraster cor-anguinum*, *Infulaster rostratus*, and *Echinocorys vulgaris*. The example of *Micraster* was, for Yorkshire, well preserved, and exhibited all the essential features of the test characteristic of this zone. It would be difficult to exaggerate the importance of this specimen, for it proves beyond all doubt that, though *Micraster* is one of the rarest fossils in this zone on the Yorkshire coast, its essential features in no particular differ from those of the common fossil in the South of England.

It will be seen that pits 5 to 10 are all in the zone of *Micraster cor-anguinum*; No. 5 is in flintless chalk, such as we find south of the Headland; Nos. 6 and 7 are in the chalk with scattered nodular flints, such as we find on the south side of High Stacks, about 100 ft. from the base of the zone; and Nos. 8, 9, and 10 are in the chalk with tabular bands of flint, such as we see between High Stacks and Stottle Bank Nook. The three latter pits prove beyond all question that the chalk between Kindle Scar and Stottle Bank Nook must be assigned to the base of the *Micraster cor-anguinum*-zone and not to the top of that of *Micraster cor-testudinarium*.

No. 11 (300). [M. t.] A small pit in flintless chalk one-sixth of a mile south-east of Maiden's Grave Slack. We collected here *Marsupites testudinarius*, *Rhynchonella reedensis*, and *Ostrea wegmanniana*. The last occurred in a band, and the first were quite abundant.

No. 12 (175). [M. t.] This is a small pit in flintless chalk on the east side of the Lynhams Road, and half a mile north of Marton Hall, which yielded *Marsupites testudinarius*, *Cidaris hirudo*, *Ostrea vesicularis*, and *Ostrea wegmanniana*.

No. 13 (300). [U.] A pit of medium size in flintless chalk at Speeton Station. Dr. Barrois records *Echinocorys vulgaris*, and the workmen told us that they find Belemnites (*Actinocamax granulatus*) there. We had the good fortune to find several small but perfectly characteristic plates of *Uintacrinus*, as well as arm-ossicles; so that we have the satisfaction of recording the first occurrence of this crinoid in a Yorkshire quarry.

No. 14 (338). [A. q.] A small pit in flintless chalk at the junction of the New Road to Speeton with the Scarborough Road. *Inoceramus lingua*, *Hamites*, *Rhynchonella reedensis*, *Ventriculites infundibuliformis*, and the calcite sponges were found.

No. 15 (330). [A. q.] A pit of medium size in flintless chalk at Longlands in which *Actinocamax granulatus*, *Hamites*, *Inoceramus lingua*, and *Ventriculites infundibuliformis* were obtained.

No. 16 (350). [A. q.] Very small exposure on north side of Speeton Gate, and south-east of Buckton Hall. Practically no exposure, as pit almost ploughed-out; but chalk on soil yielded *Inoceramus lingua* and *Ventriculites infundibuliformis*. Flintless chalk.

No. 17 (350). [A. q.] A rather large pit, 550 yards south-east of Buckton Hall, in flintless chalk. Excellent exposure, but fossils singularly rare. We only obtained a fragment of *Inoceramus* (?) *lingua*, and spines of *Cidaris hirudo*; but the quarrymen tell us that fossils which we consider to represent *Actinocamax*, *Echinocorys vulgaris*, and *Scaphites* are found.

No. 18 (320). [A. q.] A small pit in flintless chalk one-sixth of a mile east of Carter Close Lane. It was grassed over, but chalk on soil yielded *Ostrea wegmanniana* and *Ventriculites infundibuliformis*.

No. 19 (310). [A. q.] A pit of medium size in flintless chalk at Huntow. We here found *Inoceramus lingua*, *Cardiaster ananchytis*, *Rhynchonella reedensis*, and *Ventriculites infundibuliformis*.

No. 20 (300). [A. q.] A pit of medium size in flintless chalk at North Dale in which we collected *Scaphites* sp., *Hamites*, *Inoceramus lingua*, *Rhynchonella reedensis*, *Pecten cretosus*, *Ostrea wegmanniana*, and *Ventriculites infundibuliformis*.

No. 21 (250). [A. q.] A pit of medium size in flintless chalk at East Leys. We here found *Inoceramus lingua*, *Kingena lima*, *Pecten cretosus*, *Avicula tenuicostata*, and calcite sponges.

West Side of Thornwick Bay, Looking towards Bempton Cliffs.

No. 22 (343). [A. q.] A pit of medium size in flintless chalk half-a-mile north of Huntow, on the east side of Scarborough Road. In this we obtained *Inoceramus lingua*, *Scaphites binodosus*, *Avicula tenuicostata*, *Rhynchonella reedensis*, and calcite sponges.

No. 23 (300). [A. q.] A poor exposure in flintless chalk on the south side of Sheepwalk Lane. It was almost grassed over, but we managed to find *Inoceramus lingua*, *Ostrea wegmanniana*, *Ventriculites infundibuliformis*, and calcite sponges.

No. 24 (219). [A. q.] A pit of medium size in flintless chalk one-sixth of a mile south of Graeme's Barn. We collected *Inoceramus lingua*, *Ostrea wegmanniana*, *Ostrea vesicularis*, *Avicula tenuicostata*, and calcite sponges.

No. 25 (225). [A. q.] A small pit in flintless chalk half-a-mile north of Flamborough Station, which yielded *Inoceramus lingua*, *Ostrea wegmanniana*, and *Ostrea vesicularis*.

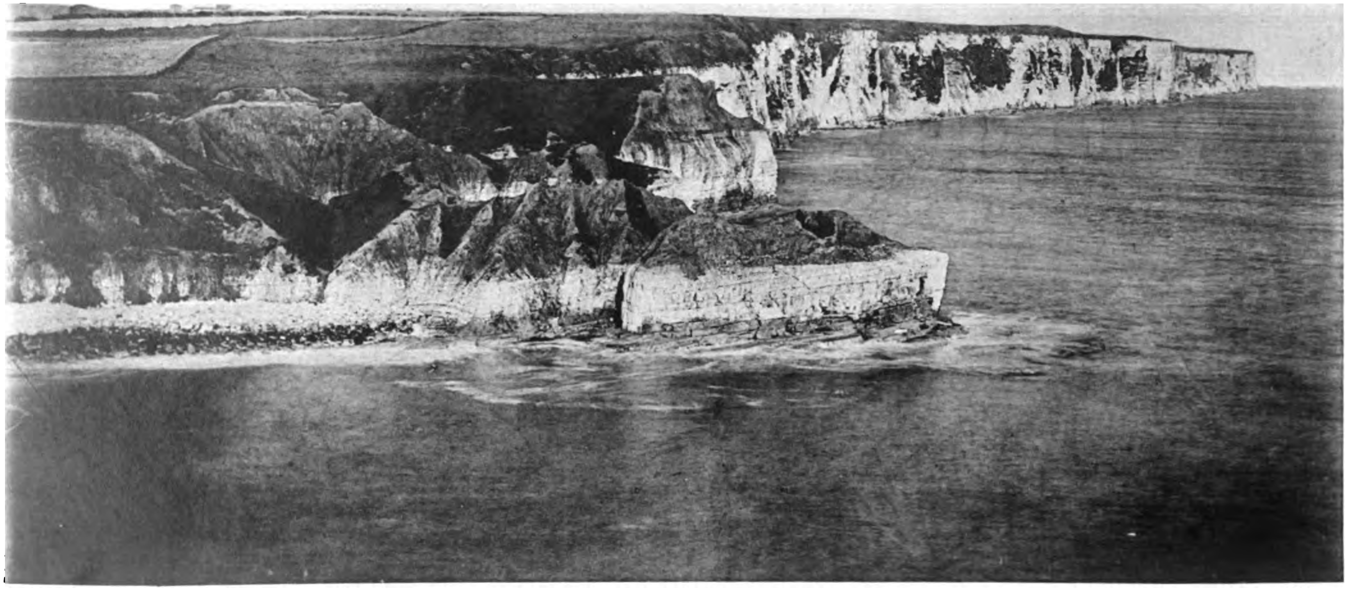
No. 26 (175). [A. q.] A very extensive quarry in flintless chalk at Flamborough Station. We obtained here *Inoceramus lingua*, *Cardiaster ananchytis*, *Echinocorys vulgaris*, *Actinocamax granulatus*, *Hamites*, *Rhynchonella reedensis*, *Kingena lima*, *Pecten cretosus*, *Ostrea wegmanniana*, *Ostrea vesicularis*, *Ventriculites infundibuliformis*, and calcite sponges.

This quarry is hewn in the base of the *quadratus*-chalk, for Mr. Stather tells us that in sinking the well at Flamborough Station plates of *Marsupites* were found. Pit No. 12, which yielded *Marsupites*, is also on the 175 ft. contour-line. Apart from the presence of *Marsupites* in the well and in Pit No. 12, the shallowness and ovate section of the alveolar cavity of *Actinocamax* would have fixed the horizon with sufficient certainty.

No. 27 (194). [A. q.] A large quarry in flintless chalk at White Hill. This yielded *Inoceramus lingua*, *Scaphites binodosus*, *Scaphites* sp., *Echinocorys vulgaris*, and *Ventriculites infundibuliformis*.

No. 28 (150). [A. q.] A large pit in flintless chalk in Stone Pit Wood. Chalk exceedingly hard and massive, and very regularly bedded. Fossils are rare, but we obtained *Actinocamax granulatus* and *Ostrea vesicularis*.

No. 29 (53). [A. q.] Large pit on the north side of Bessingby Hill in flintless chalk, in which we found *Actinocamax granulatus*, *Aptychus*, *Cardiaster ananchytis*, *Inoceramus lingua*, *Ostrea wegmanniana*, and calcite sponges.



WEST SIDE OF THORNWICK BAY, LOOKING TOWARDS BEMPTON CLIFFS.

No. 30 (100). [A. q.] A smaller pit on the south side of Bessingby Hill in flintless chalk. This yielded *Actinocamax granulatus*, *Scaphites binodosus*, *Scaphites* sp. (2 forms), *Cardiaster ananchytis*, *Micraster*, *Rhynchonella reedensis*, *Ventriculites infundibuliformis*, and calcite sponges.

No. 31 (150). [A. q.] A pit of medium size in flintless chalk at Hopkins' Lane, Carnaby. Fossils are rare, but we found *Echinocorys vulgaris*, and a scattered band of *Cardiaster pillula* at the top of the pit.

No. 32 (150). [A. q.] A pit in flintless chalk north of the church at Carnaby. This is on the same level as No. 31, for we found *Cardiaster pillula* here also, and *Actinocamax granulatus* as well.

No. 33 (150). [A. q.] Pit at Ruston Parva in flintless chalk half-a-mile north of the Church. *Actinocamax granulatus* has here the deepest and most quadrate alveolar cavity, so this is probably the highest chalk in the area under examination (see p. 271, Fig. 12). In addition we obtained *Echinocorys vulgaris*, *Inoceramus lingua*, and calcite sponges.

No. 34 (100). [A. q.] Pit in flintless chalk at Burton Agnes. Both this pit and No. 33 are not within the area of the map (Pl. XL), though No. 33 is noted on the margin. We found here *Actinocamax granulatus*, *Hamites*, *Echinocorys vulgaris*, and *Ventriculites infundibuliformis*.

It will be seen that Nos. 14—34 are in the zone of *Actinocamax quadratus*. It is in quarries in this zone that local collectors will obtain the richest results, for not only are the exposures more numerous, but the fossils more abundant. It will at once be noticed that *Actinocamax granulatus* is not recorded for a number of these quarries. This does not imply that it is not there, but simply that in our rapid survey of the pits we did not find it. We subsequently ascertained from Mr. Lamplugh and Mr. Stather, and in several instances from the workmen, that this belemnite is to be found in a number of the pits in which we failed to obtain it.

Our collecting in the quarries is confessedly rapid and incomplete, as our object was merely to zone each pit for mapping purposes. But even this hasty survey brings out several points of interest. We have indicated that the deepest and most quadrate alveolus of *Actinocamax granulatus* was found at Ruston Parva (No. 33). So thoroughly have we learned to trust this feature in the field that we have no hesitation in fixing the relative age of an horizon in the *quadratus*-chalk by this condition alone. A second point is that *Scaphites* runs in

bands, and that it occupies a high level in the zone; and that *Micraster*, found only in the pit south of Bessingby Hill, also occurs only in the higher beds, and at a remarkably restricted horizon. Further, it will be noticed that the calcite sponges are not present in bulk at all levels, and that they also run in bands. Though *Inoceramus lingua* and *Ventriculites infundibuliformis* are not recorded in all instances, we have little doubt that further search will result in finding them in practically every exposure.

Zoological Summary.

We again follow our usual course, and give a tabular and detailed summary of the zonal guide-fossils, emphasising the fact that each summary applies to the Yorkshire coast alone. We make no excuse for the meagre lists of fossils, for the Yorkshire Chalk is proverbial for its barrenness. Our object has been to bring these obscure and unprolific sections of the north into line with the simple and richly fossiliferous beds of the south. Our results are confessedly incomplete and tentative, and we have made no effort to do more than roughly indicate the fauna of these difficult but most interesting sections. Having, as it were, provided the skeleton, we leave it to the capable and enthusiastic geologists of Yorkshire to clothe these dry bones with living flesh.

As we shall show when we deal with the zones in detail, we have already in this rapid traverse of the Yorkshire coast introduced to southern geologists not a few forms with which they are unfamiliar. But to us the most fruitful and suggestive phase of the work has been the manner in which we have been able to extend the knowledge of the vertical range of several important guide-fossils, in some instances by hundreds of feet, and thus to bridge over gaps in the zoological record. Nothing has appealed to us more strongly than the way in which rigid zonal collecting over the bulk of the chalk-bearing counties has enabled us, little by little, to close up the gaps in the vertical range of one group after another. Hardly less interesting is it to follow out the horizontal distribution of certain groups, thereby educing the fact that a fossil which occurs but sporadically in one area may develop richly in another. When our knowledge of the English fauna is less incomplete we shall be able more effectively to correlate it with that of the Continent. Dr. Barrois showed that the fauna of the Yorkshire *quadratus*-chalk corresponds with that of North-West Germany, and as more fossils new to our English rocks are discovered, so shall we find that certain forms, hitherto known only in Continental areas, have their place in English sections as well.

It would not at all have surprised us if we had been unable to exactly correlate the zones in Yorkshire with those in the

south of England. While nowhere do we see the workings of local variation in geographical distribution more strongly in evidence than in this county, we are still able to trace the continuity of zonal life-forms, though in certain instances in a markedly attenuated manner. For instance, *Micraster* is one of the rarest fossils on the Yorkshire coast, but even here the essential features of the test run so true that we have been able to zone cliff-sections and pits by the presence of this echinid alone, and to allocate to their proper horizon fossils associated with it in local collections and museums. In the same way, though the fauna of the zone of *Actinocamax quadratus* is here remarkably different from that in southern counties, we still find *Cardiaster pillula*, though in sadly diminished numbers. The urchin is in its true horizon, and is absolutely confined to it, though its numerical strength is too insignificant to enable it to take the place, which it does in the south, as the best and most reliable guide-fossil to the zone in question.

Again, *Echinocorys vulgaris* fails us in Yorkshire as a zonal guide, not because it is rare, but because an uncrushed example is quite a possession in local collections. Six weeks' work in the five higher zones did not yield us more than eight well-preserved examples. From such imperfect material as we were able to utilise, we are, however, of opinion that the shape-variations, which are of such high value as zonal guides in the south, are somewhat different in the north. This is a question which can only be settled at a future date; and now that we have fixed the zonal limits on the coast, and have cleared up much of the uncertainty about the horizon of the quarries, we look to Yorkshire geologists to make a zonal collection of this important fossil.

As we have already endeavoured to show in "An Analysis of *Micraster*,"* the species question becomes very nebulous and uncertain when we come to deal with a large and plastic group, especially when such a group is found in vast numbers, and is spread over a wide area. It is much the same with the belemnites, as we have indicated when dealing with this group.† The unbroken transition which we have there demonstrated between *Actinocamax westphalicus*, *A. granulatus*, and *A. quadratus*, obtains a striking corroboration in Yorkshire, for here we can trace *Actinocamax granulatus* in flawless continuity, from the base of the flinty beds of the *Micraster cor-anguinum*-zone to the highest chalk of the area—the *quadratus*-chalk of Ruston Parva. For though the species persists as *Actinocamax granulatus* all the while, we can trace, as we ascend the zones, a steady deepening of the alveolar cavity, and an approach to the quadrate section of that cavity,

* *Quart. Jour. Geol. Soc.*, vol. lv, Aug. 1899.

† The Zones of the White Chalk of the English Coast. Part II, Dorset. *Proc. Geol. Assoc.*, vol. xvii, pp. 49, 50, 1901.

which brings us within measurable distance of the features of the true *Actinocamax quadratus*. Still, as we have pointed out elsewhere (p. 225), *Actinocamax quadratus* in its full development has yet to be collected in this area; and the explanation of the fact that we have not obtained it is probably found in the assumption that the higher beds of this zone, in which we might reasonably have expected that *Actinocamax* would have evolved as far as the stage which we know as *Actinocamax quadratus*, have been removed by denudation: just as in the case of the *Belemnitella mucronata*-zone, which is only known from the presence of its name-fossil in the Holderness drifts. Mr. Lamplugh considers that the latter belemnite was probably brought in from the north-eastward of the present coast of Holderness. We deal with the subject of the belemnites in Yorkshire on p. 270.

Zone of Rhynchonella Cuvieri.

(West of Kit Pape's Spot.)

A *Rhynchonella cuvieri*-zone 11 ft. in thickness, and at the same time very badly exposed, is hardly likely to furnish a satisfactory list of fossils, especially when it can be worked for a distance of only a few feet. We give on p. 202 a slightly better list from the same zone at South Ferriby Pit, on the south side of the Humber.

Rhynchonella cuvieri .	3	Found throughout the zone. Thickness 11 ft. 4 in.
Inoceramus mytiloides .	3	
Inoceramus lamarcki .	2	
Terebratula semiglobosa .	3	

We found no evidence of the peculiar fauna which we have recently described in the Devon paper, such as the wealth of spines of *Cidaris hirudo* and *Cidaris clavigera*, and *Cardiaster cretaceus*.*

Doubtless local collectors will in time add to this meagre list, and we would direct their attention to a section near Nanny Goat's House, mentioned by Mr. William Hill,† which entirely escaped our notice. After we had learned of this section we made a special visit to examine it, but the fog was so dense that we could not even find Nanny Goat's House. Fossils to be sought for are *Hemiaster minimus*, *Discoidea dixoni*, *Cardiaster pygmæus*, *Echinoconus subrotundus*, *Echinoconus castanea*, *Salenia granulosa*, *Glyphocyphus radiatus*, *Ammonites peramplus*, *Ammonites cunningtoni*, *Terebratula semiglobosa* var. *albensis*, *Ostrea*

* The White Chalk of the English Coast, Part III, Devon. *Proc. Geol. Assoc.*, vol. xviii, p. 32.

† W. Hill. On the Lower Beds of the Upper Cretaceous series in Lincolnshire and Yorkshire. *Quart. Journ Geol. Soc.*, vol. xliv, p. 366.

vesicularis, and *Serpula avita*. These forms are all common in the southern counties.

In none of the local collections did we notice any of the fossils belonging to this zone. For our own part, insignificant though our list of fossils may be, we were fully content to define the zone at all by the presence of *Inoceramus mytiloides* and *Rhynchonella cuvieri*. Those who take the trouble to examine this miserable little section will, we think, share our satisfaction.

Zone of Terebratulina gracilis.

Terebratulina gracilis .	C.	Common throughout the zone. Estimated thickness of zone at Crowe's Shoot 210 ft.
Rhynchonella cuvieri .	C.	
Holaster planus . .	C.	
Inoceramus lamarcki .	C.	
Inoceramus brongniarti .	R.C.	

Other characteristic fossils are *Echinoconus subrotundus*, *Hemiaster minimus*, *Salenia granulosa*, *Cyphosoma radiatum*, *Terebratula semiglobosa*, and *Ostrea vesicularis*.

Terebratulina gracilis is really fairly abundant in this zone, especially at Thornwick, where we noted forty-five examples, and then ceased to keep a record of them. This brachiopod is difficult to find, as it always exists as a crumbling iron-oxide pseudomorph. However, that this important zonal fossil should never have been recognised on this coast before is not a little remarkable. In the Mortimer Museum there is an example of the fossil from Burdale.

Rhynchonella cuvieri, both at Speeton and Thornwick, is as common as in its own zone. All examples, however, are much crushed and decomposed by iron, and we did not obtain a single good specimen.

Holaster planus is as common in the *gracilis*-beds as in its own zone. At Thornwick, indeed, it is found in profusion, but is always in a poor state of preservation.

Inoceramus lamarcki and *I. brongniarti* are also really common here, and the ledges of Thornwick Bay afford the only chance on this coast of obtaining fairly perfect examples of these lamellibranchs. *Inoceramus cuvieri* is also abundant, and we found one 2 ft. in diameter.

Dr. Barrois (p. 200) records *Echinoconus subrotundus* from Hessle quarry, and we have seen one example at South Ferriby, on the south side of the Humber. This specimen was much more pointed, and with a flatter base, than is usual in this zone. We did not find it at Speeton or Thornwick.

Hemiaster minimus, *Salenia granulosa*, and *Cyphosoma radiatum* are all rare. The last two are remarkably small, for

the two examples of *Salenia* measured only 3½ and 3 mm. in diameter, and the *Cyphosoma* but 6 mm. One *Salenia* was found in the middle quarry at Barton-on-Humber, so the small size must be something more than a coincidence. *Hemiaster minimus* was found both at Speeton and Thornwick, and was of ordinary size; while *Terebratula semiglobosa* was both abundant and of large size in every section of the zone. *Ostrea vesicularis* was of the same shape and size as in the south. We refer to this oyster in the Devon paper,* and its occurrence in Yorkshire only confirms our opinion of its usefulness as a zonal guide-fossil.

Spines of *Cidaris hirudo* are the only cidarite remains which we found, and they are rare; and a small lateral tooth of *Ptychodus* from Speeton was the only evidence of vertebrata. We record a single example of *Crania egnabergensis*, which in Yorkshire has an unbroken range from this zone to that of *Actinocamax quadratus*.

At Crowe's Shoot we noticed a thin band of *Ostrea proboscidea* in the extreme base of the zone. We shall mention it again in the *Holaster planus*-zone (p. 243) at North Sea Landing.

Probably one of the most interesting records is that of *Kingena lima* in this zone at Reighton. We have recently found it in the zone of *Rhynchonella cuvieri* at Dover, so that we are gradually closing up the gaps in the vertical range of this brachiopod. Dr. F. L. Kitchin agrees with us in the determination of this fossil.

That this hard rock should contain Bryozoa is hardly to be expected, but we found an excellent example of *Melicertites globulosa* in an air-weathered surface at Crowe's Shoot.

We failed to find *Micraster cor-bovis*, *Discoidea dixoni*, *Pentacrinus*, *Spondylus spinosus*, *Spondylus latus*, or *Spondylus dutempleanus*, and we commend these omissions to the notice of Yorkshire geologists. The singular absence of iron-oxide sponges, such as *Guettardia stellata*, *Craticularia fittoni*, and *Cephalites*, so common in the south, is quite notable. *Porosphæra globularis* is unusually rare in this zone, but is of the customary small size, and measures about 2 mm. in diameter.

Zone of Holaster planus.

Holaster planus	Common throughout the zone. Approximate thickness, 125 ft.
Echinocorys vulgaris var. *gibbus*?	
Micraster præcursor (inland only)	
Pentacrinus	
Ostrea proboscidea	
Inoceramus brongniarti.	

Other characteristic fossils are: *Rhynchonella cuvieri*, and *Inoceramus lamarcki*.

* *Op. cit.*, pp. 34, 35.

Our list for this zone is almost entirely compiled from North Sea Landing and the adjacent ravine rejoicing in the euphonious title of Holmes' Gut. The only other accessible section which we know of on the coast is situated at Crowe's Shoot, in Speeton cliffs.

Holaster planus may be said to be common, as we counted thirty examples in North Sea Landing alone, and then ceased to keep a record of it. It has hitherto been regarded as extremely rare in this bay, but the grounds for such a supposition are not very apparent. It would seem that this urchin has even more claim to the title of name-fossil to this zone in Yorkshire than it has in the south, for here we have to rely entirely on it, and its association with *Echinocorys vulgaris*, as a guide to horizon, in the complete absence of *Micraster præcursor*, *Micraster cor-bovis*, and *Micraster leskei*. Examples of *Holaster planus* are to be found in the Mortimer Museum from Ackland Wold, Beverley, Wharram Percy, and Uncleby Stoop. This does not of necessity imply that they are derived from the zone of the same name.

Echinocorys vulgaris is also not uncommon, and it appears to be of the var. *gibbus*. With the exception, however, of a single small example found at Crowe's Shoot, all the specimens which we collected were too crushed to render this point at all certain.

Pentacrinus is also not rare. Mr. Lamplugh, indeed, is of opinion that there is a band of this crinoid at North Sea Landing. We, however, failed to find it. We have always regarded the large columnars of *Pentacrinus* as a useful guide-fossil to this zone, and were, therefore, not surprised to find it here. What was a source of astonishment to us was the fact that the shape of the columnars, instead of being angular, is rounded, thereby much more resembling the outline of *Pentacrinus bronni* of the *Belemnitella mucronata*-zone of Norwich. We have not found *Pentacrinus* in any other zone in Yorkshire.

To be able to record an oyster which, so far as our knowledge goes, is new to the English Chalk, is a matter of some importance. We found in North Sea Landing a thick band of *Ostrea proboscidea*, d'Archiac.* The occurrence in quantity of a characteristic and readily recognisable fossil will be a boon in inland sections of this zone, for, as we have already shewn, *Holaster planus* is as common in the *gracilis*-beds as in its own horizon. *Terebratulina gracilis* itself is, except to the experienced, so difficult to find in inland sections, that there must always be a certain amount of hesitancy in separating these two zones in quarries, when the characteristic brachiopod is not forthcoming. At the risk of repetition we would emphasise the fact that the association of *Echinocorys* with *Holaster planus* at once stamps a section as belonging to the *Holaster planus*-zone, and not to that of *Terebratulina gracilis*. Though *Ostrea proboscidea* occurs in

* Coquand. Monographie du genre Ostrea. Terr. Cret., p 72, Pl. XVI, Figs. 3—6.

the extreme top of the *Terebratulina gracilis*-zone at Crowe's Shoot, it only is found in abundance in the higher zone, and may, therefore, be regarded as a new and distinctly useful guide-fossil to the *Holaster planus*-zone in Yorkshire. It will be interesting to see if local geologists find it in inland sections. The thickness of the shell at once catches the eye, for in proportion to its size it is much thicker than that of any oyster with which we are familiar. One example was 2½ inches in length.

Hardly less interesting than the discovery of this oyster is the occurrence of an example of *Kingena lima* in this zone. We have recently noted its existence in the *Rhynchonella cuvieri*-zone of Dover,* and again in the *gracilis*-chalk of Reighton (p. 242), and it has, therefore, been left to unfossiliferous Yorkshire to bridge over two gaps in the vertical range of this brachiopod. The only zone in which we have not now recorded it is that of *Micraster cor-testudinarium*, and doubtless we shall soon fill in this link in the chain of evidence. It would be difficult to give a more convincing example of the way in which the vertical range of a fossil can be extended by patient zonal collecting, for a few years ago we had no record in England of the occurrence of this fossil below the horizon of *Micraster cor-anguinum*.†

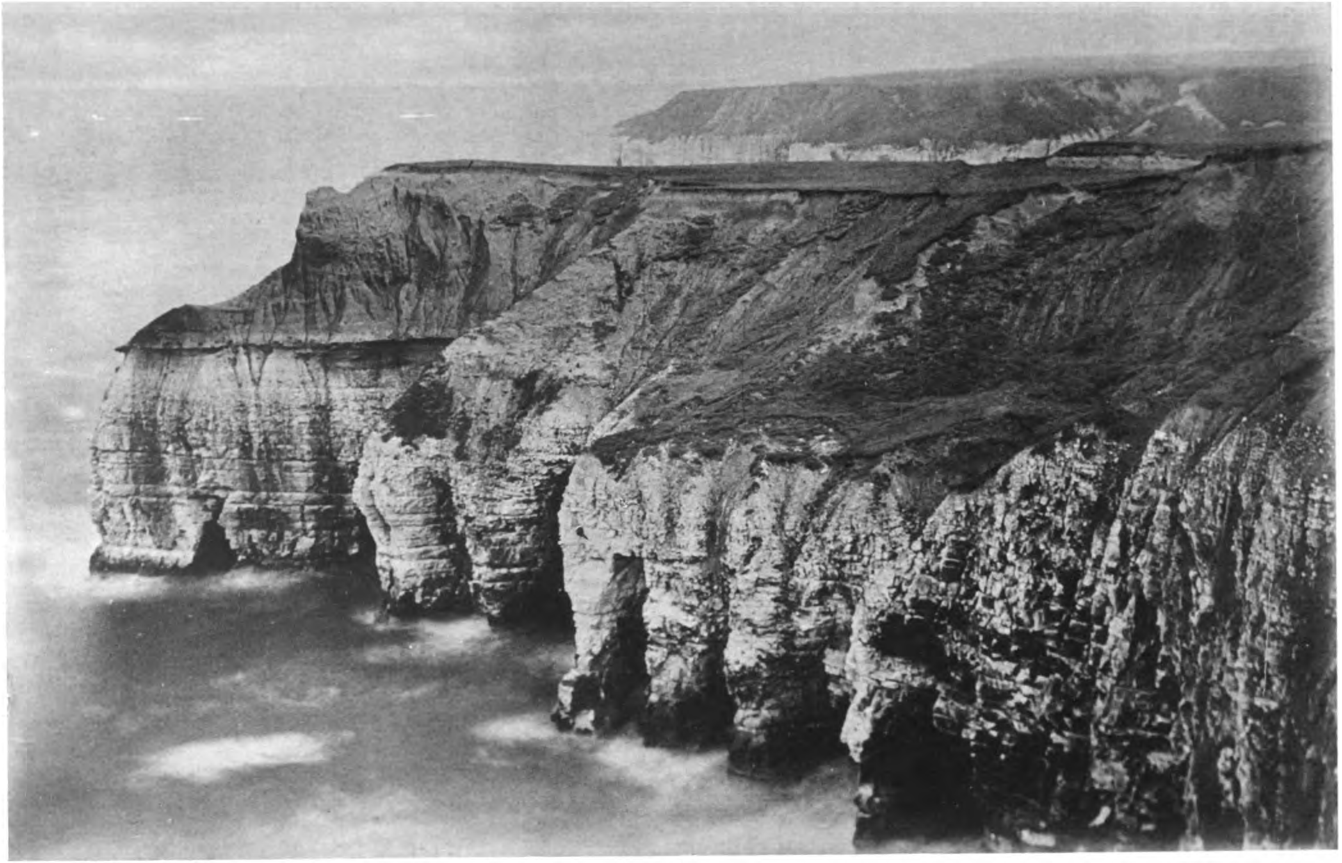
Inoceramus brongniarti, and, to a less extent, *Inoceramus lamarcki*, are common; but they are not so abundant as in the zone immediately below. The small *Inoceramus* sp., which is figured by Mr. Woods in his monograph on the Chalk Rock (Pl. xxvii, figs. 14, 15), and which we mention on p. 314 of the Kent and Sussex paper, has not yet been found in Yorkshire.

Rhynchonella cuvieri is fairly common, and as in all southern sections, is not found above this horizon. *Rhynchonella reedensis* is represented by a single example, and is therefore rarer than in the south. Our lowest record in Yorkshire is in the highest beds of the *gracilis*-zone, and this occurrence conforms to our experience in the rest of England.

We generally expect to see *Terebratula semiglobosa* and *Terebratula carnea* both abundant and of large size in this zone, and we regard this element of quantity and size as highly characteristic, especially in relation with the latter fossil. Here, however, though rather common, they are both notably small, and *Terebratula carnea* has not its usual numerical preponderance. Indeed, curiously enough, it is only in the zones of *Rhynchonella cuvieri* and *Terebratulina gracilis* that *Terebratula* reaches an average size. In all other zones on the Yorkshire coast it is quite a dwarfed form.

* Part III, Devon, p. 36.

† Since writing the above we have again visited the Dover section (Nov. 1903), and are now able to record three examples of this brachiopod in the zone of *Micraster cor-testudinarium*. The zonal sequence is, therefore, complete.



SANWICK BAY, WEST OF THORNWICK.

Rhynchonella plicatilis also, usually so large and abundant, figures in our list as a solitary small example; and *Crania egnabergensis*, generally so common at this horizon, is represented by but two small specimens.

But, after all, it is not so much for the fossils which we are able to record, as for those which are missing, that this zone in Yorkshire is remarkable. A section of the *Holaster planus*-zone in which we are unable to find *Micraster*, *Cyphosoma radiatum*, *Spondylus spinosus*, *Spondylus latus*, gasteropods, cephalopods, *Plicatula barroisi*, and *Serpula ilium*, and where *Cidaris*, *Parasmilia*, and Bryozoa are conspicuously rare, is surely one of the curiosities of Chalk palæontology.

That *Micraster* does not occur on the coast does not of necessity imply its entire absence in inland sections. In the local collections of Mr. Stather, Mr. Crofts, and Dr. Walton, we find no examples of this urchin which we can refer to the *Holaster planus*-zone, but in the famous Mortimer Museum at Driffield we have discovered four specimens of *Micraster præcursor* which undoubtedly came from this horizon. Two of these examples have "sutured," and two have "faintly inflated" ambulacra. They were all specimens of considerable size, but unfortunately none of them were marked with any indication of locality, nor could Mr. Mortimer supply the omission from memory. The broad form of this urchin, which is known in England as *Micraster cor-testudinarium*, and in France as *Micraster decipiens*, has not yet been found in this zone. We have noted that in this zone in Devon (Part III, p. 42) this form is represented by a solitary example. Neither *Micraster cor-bovis* nor *Micraster leskei* are to be found in any of the local collections.

Cyphosoma is one of the rarest genera in Yorkshire. We have recorded two dwarfed examples of *Cyphosoma radiatum* in the *gracilis*-beds of Speeton; and one of *Cyphosoma corollare* in the *Micraster cor-anguinum*-zone, and four in that of *Actinocamax quadratus* in the flintless chalk south of Flamborough Head; but we failed to obtain a single example of *Cyphosoma radiatum* in the zone of *Holaster planus*, where it is usually so abundant.

Dr. Barrois records a spine of *Cidaris hirudo* from North Sea Landing, but we failed to find either this species or any other. It must be very rare. It appears to be the one species of *Cidaris* which is found in all the zones in Yorkshire, save that of *Rhynchonella cuvieri*.

Spondylus as a genus is almost equally rare, and *Spondylus spinosus*, so far as our information serves us, has never been found in any zone on this coast. We have no record of it in any of the local collections.

Gasteropods and Cephalopods find no place in any of the

collections which we have examined; but as they are somewhat rare fossils, save where the Chalk Rock is developed, the omission is not of great significance. This is the only section of this zone, however, in which we have not recorded *Pleurotomaria perspectiva* and *Turbo gemmatus*.

Plicatula barroisi, usually so common at this horizon, is missing; and, indeed, we have yet to see it in the Yorkshire Chalk. *Ostrea*, which is generally well represented, is notably scarce. Two examples of *Ostrea hippopodium* and three of *Ostrea vesicularis* are our only record, save in the case of *Ostrea proboscidea*, which we have already mentioned.

We carefully searched for *Cardiaster cotteaui*, but failed to find it. The importance of this observation will be seen when we deal with the zone of *Micraster cor-testudinarium*, for there a band of the narrow and depressed zonal variation of this urchin is found in the lower part of that horizon.

We are so used to a profusion of Bryozoa in this zone in the southern counties that we expect to see a small fauna here; but we are only able to record *Melicertites globulosa* and *Melicertites semiclausa*, neither of which have any zonal significance.

Sponges are usually abundant at this horizon, but our list shows but a solitary example of *Ventriculites impressus*, usually a very common fossil in this zone. *Porosphæra globularis* and *Porosphæra pileolus* are notably rare, but in size they are characteristic of the horizon.

Those who, like ourselves, are used to a luxuriant fauna in this zone, will be disappointed with its barren counterpart in the North. Yorkshire geologists, therefore, have a fine opportunity for extending our confessedly meagre lists, and may perhaps bring the fauna more into line with that in southern sections. Possibly inland exposures may be discovered which are richer than those on the coast. In any case, they could hardly be more barren than those which we have now described.

Zone of Micraster cor-testudinarium.

Micraster præcursor, of group-form associates with this zone. *Echinocorys vulgaris*.	Throughout the zone.
Cardiaster cotteaui (lower one-third of zone).	Approximate thickness, 125 ft.

The exposures of this zone are so small and inaccessible that it is impossible to put forward a tabular list of guide fossils which can have more than a tentative value. Later on, when more data are available, we shall be prepared to modify this table, so as to give to any new facts their proper importance.

As no fossil has yet been discovered on the coast which is sufficiently common and characteristic to occupy the position of name-fossil, we have retained the old title, inappropriate though it be, as a zone must have a temporary label to indicate its position in the series.

Though *Micraster præcursor*, of the group-form associated with this zone, is found at Breil Head, and in inland sections, it is too rare to adequately fill the position of name-fossil. The broad form, which in England we know as *Micraster cor-testudinarium*, and which in France is called *Micraster decipiens*, is also too rare to be of service. Indeed, we only know of one example, and this came from the Kirkella Cutting, near Willerby, and is in Mr. Stather's collection. The rarity of the broad form finds a complete parallel in the same zone in South Devon (Part III, Devon, p. 44). It is eminently satisfactory to note, however, that *Micraster*, though comparatively rare locally, rigidly coincides in the essential features of the test with its congeners in the south. Therefore, when it is found, it is an absolutely trustworthy guide to horizon. Examples of *Micraster præcursor* may be seen in the collections of Mr. Stather and Dr. Walton, and there is a good series in the Mortimer Museum from the Etton Cutting. It is only right to say that this urchin is evidently more common inland than on the coast, and that further collecting in railway cuttings and quarries may prove that it is more abundant than we suspect, and thereby establish its claim to the position of name-fossil.

There is, however, the same objection to the employment of *Micraster præcursor* as the index fossil of this zone in Yorkshire as in the south of England. It is merely a plastic group-form with distinctive zonal variations in the essential features of the test, and not a sharply defined species. The forms from the *Micraster cor-testudinarium*-zone have no specific title to distinguish them from those in the *Holaster planus*-zone; nor, indeed, do we consider that it is advisable that they should have a separate designation, as it would destroy the unity of the conception of a group-form, by which means alone can we emphasise the unbroken continuity of the evolution of this urchin as a zonal series.

We have obtained two other localities for the occurrence of *Micraster præcursor* in the Mortimer Museum, namely, Enthorpe Cutting and Wharram. Both here and in the Etton Cutting the size of this urchin is undoubtedly large. Among the examples of this urchin in the Mortimer Museum are several from Etton with "faintly inflated" ambulacra. It is clear, therefore, that in this section we have the junction of the zone of *Micraster cor-testudinarium* with that of *Holaster planus* exposed. The name-fossil of the latter zone has not yet been found there.

Echinocorys vulgaris, though relatively commoner than

Micraster on the coast, is so badly preserved that its shape-variations cannot be recognised. We cannot, for this reason, employ it as a name-fossil. In this zone we notice that a number of these urchins have thin tests.

An interesting record is that of *Cardiaster cotteaui* in this zone at Newcombe. Mr. Lamplugh collected three examples there, and we found two other fragments; so the fossil cannot be really rare. It probably exists as a band in the lower-third of the zone only, as we did not find it at Breil Head, though we carefully searched for it. Being a readily recognisable form it may be a useful guide-fossil in inland sections, and we commend it as such to the attention of local collectors. We may mention that the examples which we have obtained correspond to the smaller, and more elongate and depressed form which we associate with this zone. We referred to this zonal shape-variation in the paper on the Devon Chalk.*

A single example of *Holaster placenta* was seen both at Breil Head and Newcombe, and we mention its occurrence as it is generally a common fossil in this zone. We especially call attention to the fact that we searched the upper part of the section at Newcombe for *Holaster planus*, but without success. The absence of *Holaster planus* and the presence of the special form of *Cardiaster cotteaui* would seem to fix the age of this Newcombe section beyond all doubt.

We obtained three examples of *Serpula turbinella* from Newcombe, and we mention the fact as it is a very rare and low occurrence for this species. We only remember to have found it once before at this horizon, and that was in the upper part of this zone at Dover.

But the newest and most interesting record is that of *Infulaster rostratus* at Breil Head. To find it in the zone of *Actinocamax quadratus* was nothing new; but to trace it down, zone by zone, to this horizon was indeed a surprise. Surely a range such as this cannot find its counterpart in the rest of England.

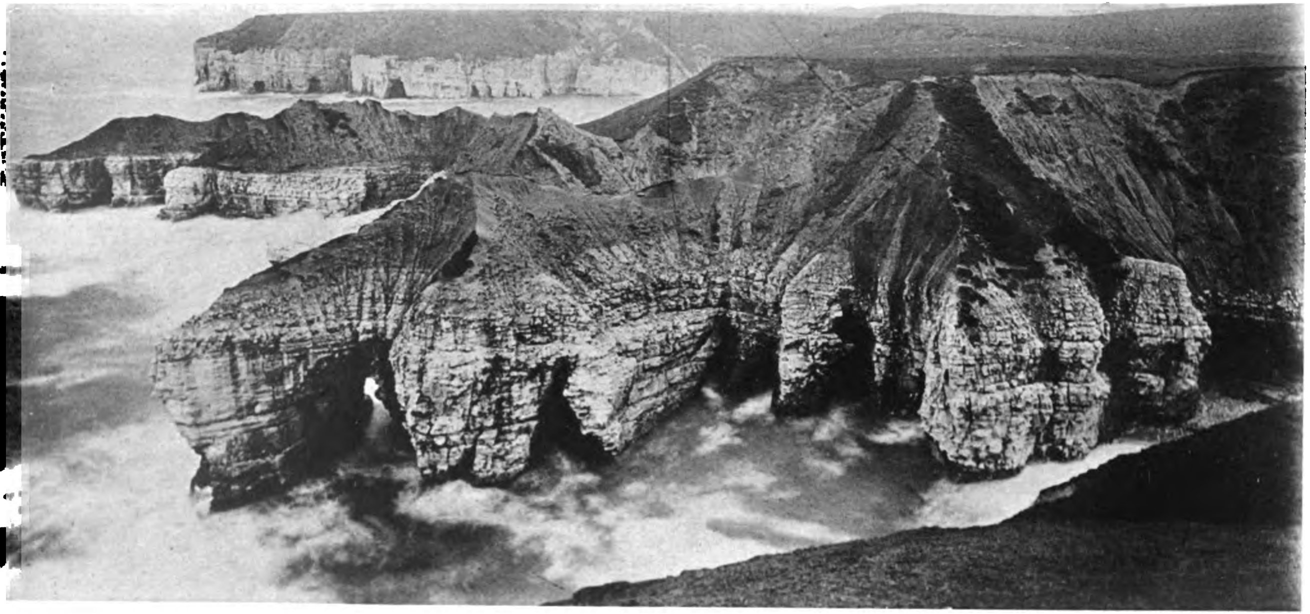
We found a small Ammonite, $2\frac{1}{2}$ inches in diameter, in Pit No. 4, which we take to be in this zone, but it was quite incapable of determination. Its chance of being named was still further reduced by the fact that it had been baked in the kiln.

Zone of Micraster cor-anguinum.

(Local equivalent—Zone of Infulaster rostratus.)

Infulaster rostratus . .	Throughout the zone.
Actinocamax granulatus .	Thickness of zone 261 ft. 6 in.

* *Op. cit.*, pp. 43, 45.



CHATTERTHROW, LITTLE THORWICK, AND GREAT THORWICK.

Associated guide-fossils:—*Micraster cor-anguinum*, *Echinocorys vulgaris*, *Actinocamax verus*, *Parasmilia centralis*, and *Serpula turbinella*.

We have already on p. 219 given our reasons for founding, for purely local use, a new equivalent title for this zone. As we shall show, when we come to deal with the belemnites, *Actinocamax granulatus* cannot be used for the name-fossil of this zone in Yorkshire, in that it merely introduces us to a zonal stage in the evolution of this remarkably persistent species. Though the shallowness of the alveolar cavity would be a good index of horizon to one well acquainted with this belemnite, it would not be sufficiently indicative to those who have not made a study of the group.

A glance at the zonal summary set forth on pp. 303 and 331 of the Kent and Sussex paper, and on p. 48 in that of Dorset, will show the wide divergence between the fauna of this zone in Yorkshire and that of the South of England. Imagine a zone of *Micraster cor-anguinum*, where the name-fossil and *Echinocorys vulgaris* are degraded to the level of mere associated guide-fossils; where *Echinoconus conicus*, *Epiaster gibbus*, *Cidaris perornata*, and *Inoceramus involutus* are altogether excluded from the table; where *Cyphosoma and Bourgueticrinus* are of no zonal utility whatever; where in place of the customary zonal forms we find a profusion of *Infulaster rostratus* and *Actinocamax granulatus*, extending from base to top of the zone; and we have as pretty a piece of zonal irregularity as one need wish to see.

It will now be necessary to discuss the more prominent fossils in detail, in order that we may show reason for the curious construction of the zoological summary of this zone.

Infulaster rostratus is so common, especially between South Sea Landing and High Stacks, that one could readily collect a hundred examples in a single day, though probably not more than five per cent. of them could be called museum specimens. So common are they at certain levels that we counted nine examples on one block of chalk 2 ft. square. We found this urchin in five out of the six pits in this zone, some of the quarries being in the tabular region of the flinty chalk, and therefore near the base of the zone. The fact that we obtained it in so many chalk pits is clear evidence that it is a useful zonal fossil in inland sections, and that it will be the means of zoning quarries which have hitherto yielded no characteristic fossil. We have already recorded it in the zone of *Micraster cor-testudinarium* at Breil Head, and we may now state that it exists in the zones of *Marsupites testudinarius* and *Actinocamax quadratus* as well. In the latter chalk we have found it 150 ft. up in the zone, but as yet the pits, which have a higher level than the Sewerby chalk, have not yielded it. This interesting echinid has, therefore, a

known range on the Yorkshire coast of nearly 700 ft.—a remarkable fact when we consider that it is usually one of the rarest fossils, and one singularly restricted in vertical range and horizontal distribution. The only places where we know it to occur are at Salisbury, where Dr. Blackmore has found about twenty examples in the upper part of the *Marsupites*-zone and the lower part of that of *Actinocamax quadratus*; and in Hampshire, where Mr. Griffith records it as a rare fossil in the *Micraster cor-anguinum*-zone. For our own part we have found but one example, and that in the *Marsupites*-band of Margate.* In the paper on Kent and Sussex we record two examples in the Wetherell collection (British Museum) from this horizon. We have recently had the opportunity of examining these specimens, and have no hesitation in describing them as ossicles of an asteroid. Yorkshire geologists have a chance of still further enlarging our knowledge of the range of this fossil, and we commend to their notice for this purpose the zone of *Holaster planus*, and the highest *quadratus* chalk in the pits at Bessingby, Burton Agnes, and Ruston Parva.

Micraster cor-anguinum is on the coast one of the rarest fossils in its own zone. Inland it would appear to be much more common, for Mr. H. A. Allen, of H.M. Geological Survey, tells us that they are plentiful at Market Weighton. Mr. Allen has been kind enough to show us these urchins, which he collected himself, and we have no hesitation in referring them to the zone with which we are dealing. Up to the present we have found but three fragments of *Micraster* on the coast, between South Sea Landing and High Stacks, another incomplete example in a pit on the Bempton Road, and the best specimen of all at Sixpenny Hill. It is of interest to note that in every instance, where the essential features of the test were preserved, we had not the least difficulty in assigning these urchins to the zone under discussion, for they tallied in every particular with southern forms. The same may also be said for those in the collection of Mr. Stather, and in the Mortimer Museum. Even in this last famous collection this species is distinctly rare. When we complete our survey of the inland sections we shall be able to come to some decision as to the name-fossil for this zone. As far as the cliff-sections are concerned, and the quarries near the coast, it is abundantly clear that *Micraster cor-anguinum* cannot be employed for that purpose.

Echinocorys vulgaris, as a rule so valuable as a zonal guide, is here quite useless for this purpose. Though we have made special efforts to collect a series of this urchin, in order to trace

* Since writing the above we learn that Captain C. F. Bishop has found an example in the top of the *Micraster cor-anguinum*-zone of Pegwell. Further, in November, 1903. Mr. Sherborn and General C. F. Cockburn found four rostra of this species in the *Uintacrinus*-chalk of the Ringwould area, near Dover.

the shape-variations, we have not succeeded in obtaining a single uncrushed example. From such meagre evidence as we could obtain, our impression is that the shape-variations do not coincide with those in the south. There is a band of *Echinocorys* with thin tests one-sixth of a mile north of the Syke, between South Sea Landing and High Stacks.

Echinoconus conicus, though not found on the coast, is in the Mortimer Museum, and the specimens are labelled from Burdale, twelve miles from Driffield; and from the same locality we noted *Infulaster excentricus*, and *Micraster cor-anguinum* of the form characteristic of the base of this zone. *Infulaster excentricus* comes from the same horizon in Norfolk, where it was originally discovered by Mr. C. B. Rose.

As we have already said, *Actinocamax granulatus* is fairly common, but owing to the hardness of the chalk in this zone it is very difficult to remove the belemnite without damaging the outer layer of the guard, unless the fossil happens to be in a marly band. The shallowness of the alveolar cavity is very marked in this zone, especially at the base of the flintless chalk south of High Stacks (Pl. XXXIV). We have not been fortunate enough to find one of these belemnites in the flinty chalk of this zone, either on the coast or in quarries. For this reason we are the more grateful to Mr. J. R. Mortimer for the trouble which he has taken in going through all his belemnites. There are only three examples of *Actinocamax granulatus* in the Mortimer Museum which are stated to have been derived from the flinty chalk. These came from a pit between Fimber Station and the village of that name, which Mr. Mortimer says is on the 270-ft. contour-line. There are no well-marked tabular bands in this pit, so it is possible that we have here the upper part of the flinty portion of this zone. Mr. Mortimer adds that half a mile westward of this pit a well was sunk at a point 340 ft. above sea level, and that it extended to a depth of 213 ft., about 70 courses of flint being penetrated. Two belemnites were found 26½ ft. from the surface. The three examples of *Actinocamax granulatus* from the Fimber pit have been lent to us by Mr. Mortimer. Only one is in a fair state of preservation, and has an alveolar cavity. The depth of the cavity is much the same as in the examples from the base of the flintless chalk in this zone. The guard is too eroded to show any trace of granulation.

We call attention to the remarkable deformed example of *Actinocamax granulatus*, which has been figured and described by Mr. G. C. Crick in the appendix to this paper. It was obtained in the upper part of the flintless chalk of this zone, midway between Beacon Hill and South Sea Landing. Such a deformity is unique in our experience in the English Chalk.

Actinocamax verus is a rare belemnite on this coast, but it makes up for its rarity by the extent of its vertical range. Our

lowest example came from within 50 ft. of the base of the flintless chalk, south of High Stacks, in the *Micraster cor-anguinum*-zone, and the highest example within 25 ft. of the top of the *quadratus*-chalk, at Cliff End, Sewerby. But we can still further extend the downward range of this belemnite, for through the courtesy of Mr. Mortimer we have been able to examine an undoubted example, with well-preserved proximal end, which, he affirms, came from the flinty chalk of Fimber. It did not come from the same quarry which yielded the three examples of *Actinocamax granulatus* already mentioned, but Mr. Mortimer is absolutely certain that it came from the flinty chalk. This gives us an unexampled range in England for this belemnite of about 650 ft.

Ammonites are rare on this coast, and our only record for this zone is an almost obliterated specimen, about 4 in. in diameter, from the base of the flintless chalk at High Stacks. Dr. Walton has a much better example from the same horizon, but we have been unable to obtain a determination of it from anyone. Mr. Lamplugh has a portion of another Ammonite, probably of the *leptophyllus*-group, from South Sea Landing. This example is about 12 in. in diameter.

The remains of *Cidaris*, which are as a rule quite a feature of this zone, are here but poorly illustrated. The spines of *Cidaris sceptrifera* are fairly common, those of *Cidaris subvesiculosa* are rare, while *Cidaris clavigera* is represented by a solitary radiole—the only one obtained by us on the whole coast. Curiously enough we do not find *Cidaris hirudo* in our list for this zone, though we record it for all the other zones, save that of *Rhynchonella cuvieri*. The spines of *Cidaris perornata*, which we have always regarded as a guide-fossil to this zone in the south, are entirely wanting, not only in this zone, but throughout the coast.

Cyphosoma, usually a fairly abundant genus in this zone, supplied us with a single example of *Cyphosoma corollare*. Indeed, we have never worked any locality where this genus is so poorly represented in all the zones.

We have a curious record in the presence of *Cardiaster ananchytis* east of South Sea Landing, and 90 ft. from the top of the zone. As this urchin ranges up to the top of the *quadratus*-beds at Sewerby, and is also found in quarries in the *quadratus*-chalk at a higher level than the beds on the coast, we have a truly remarkable range of about 575 feet.

Brachiopods yield but a poor list in this chalk, for not only are they rather rare, but they are so permeated with iron-oxide that it is impossible to remove them in good condition. *Terebratula semiglobosa* is very small, and always crushed. The largest example measured 19 mm. × 16 mm. *Rhynchonella reedensis* is rare, and forms a marked contrast to its more frequent occurrence in the *Marsupites*-zone, and its still greater

Photo. by Shores, Bridlington.

NORTH SEA LANDING, FROM THE SOUTH.

abundance and larger size in the zone of *Actinocamax quadratus*. *Kingena lima* was represented by four examples of medium size; *Terebratulina striata* by ten specimens, mostly very small; and *Crania egnabergensis* by six notably small examples. *Crania parisiensis*, usually so common in this zone, was not found, nor, indeed, have we seen it on this coast. Mr. Lamplugh, however, tells us that he found one example, probably belonging to this species, adnate upon a sponge from the *quadratus*-chalk of Sewerby. *Thecidea wetherelli*, which from its abundance in this zone is usually regarded by us as of zonal value, was entirely wanting.

Lamellibranchs, with the exception of the ever-present *Inoceramus cuvieri*, are not in strong force. Even *Ostrea vesicularis* is by no means common, and *Ostrea wegmanniana* is represented by only two examples. In the South no zone is so rich as this in *Ostrea*, so that the restriction to two species is all the more remarkable. The rarity of *Ostrea wegmanniana* is a useful point in the field, for it runs in bands in the *Marsupites*-zone, and is found in extraordinary profusion in that of *Actinocamax quadratus*. Three examples of *Pecten cretosus*, and two of *Spondylus latus*, are all that we can record for this zone. Though we did not find it on the coast, we record *Inoceramus involutus* from Burdale, Pluckham, Walkington, Fimber Station, Riggs, and Sledmere Road. These specimens are in the Mortimer Museum. As we have not examined the above-mentioned sections, it is impossible to assign the examples of this species to the zone in question.

Parasmilia attains its maximum development in the Yorkshire chalk at this horizon, both in numbers and size, and therein in a measure it corresponds with southern sections. In Yorkshire, however, the preservation of the corals is so bad that it is difficult to determine them. This is mostly due to their destruction by iron-oxide. The bulk of the specimens belong to *Parasmilia centralis*, but we found one example of *Parasmilia granulata*.

Serpula turbinella is here not without value as a zonal guide-fossil. It is fairly common, and of large size, and we record it for both the flinty and flintless area of this zone. We have shewn that it is found in the *Micraster cor-testudinarium*-zone at Newcombe, and we shall also note it in the lower part of the *quadratus*-zone, as exposed in Sewerby cliffs. We did not obtain it in the zone of *Marsupites testudinarius*. We found five examples of a *Serpula* which is new to us. It somewhat resembles a large uncoiled *Serpula turbinella*, and is restricted to this horizon. A *Micraster cor-anguinum*-zone which yields but one example of *Serpula ampullacea* is indeed remarkable.

Bourgueticrinus entirely fails us as a zonal guide. We found eight heads, but they are all very small, and in no way resemble the characteristic zonal form of the south. Columnars are notably

commoner in this zone than in the two above it; but even here they are much rarer and smaller than at the same horizon in the southern counties.

Among the rarer fossils we obtained two examples of *Scalpellum maximum*, both of unusual size, and more resembling the dimensions of those found in the *Belemnitella mucronata*-zone. We also had the good fortune to secure a balanid of unusual form. This we submitted to Dr. Henry Woodward, who did not recognise it as a described species.

Porosphæra is useless as a guide-fossil in the Yorkshire chalk. Out of 98 examples from this zone only two could be referred to, *Porosphæra globularis* var. *nuciformis*, while *Porosphæra pileolus* more nearly approached its proper numerical proportion, and several specimens were of fair size. We record nine examples of the ordinary *Porosphæra pileolus*, nine of the var. *patelliformis*, and one of the var. *arrecta*. It will be noted that these new varietal names are those which have been given by Dr. Hinde in a paper which will shortly be published. *Porosphæra globularis* is here smaller than in the higher zones, as we should expect, but the size is much less than those from the same horizon in the southern counties. Dr. Hinde has measured these specimens and he gives the dimensions of the largest as 13 mm.; but the bulk of the examples range between 3—6 mm. in diameter.

The sponges, so richly developed in the higher zones, yield here but a poor list. We found in this zone the first example of the well-known calcified lithistid sponges, together with an instance of partial calcification of an heractinellid mainly preserved in iron-oxide. The percentage of the calcified sponges increases as we ascend the zones.

Our solitary vertebrate record is a tooth of *Oxyrhina mantelli*. We have never worked any section of this zone so poor in vertebrate remains.

Zone of Marsupites testudinarius.

Marsupites testudinarius *Actinocamax granulatus*	*Marsupites*-band, 121 ft. 1 in.	Total thickness of *Marsupites*-zone, 208 ft. 6in.
Uintacrinus *Actinocamax granulatus*	*Uintacrinus*-band, 87 ft. 5 in.	

Associated guide-fossils: *Zeuglopleurus rowei*, *Actinocamax verus*, *Ostrea vesicularis* and *Ostrea wegmanniana*.

That the whole of the flintless chalk, some 550 ft. in thickness, should belong to the chalk of *Marsupites* alone, as indicated by Dr. Barrois, seemed an incredible measurement for this zone, even in this land of strange happenings. The

measurements which we give are in themselves sufficiently large, for our greatest measurement hitherto obtained for a complete exposure on the coast amounted to 111 ft.,* though the incomplete exposure of Margate measured but 116 ft.† We shall refer to the question of measurements in the section of this paper devoted to this subject.

A glance at the zonal summary will at once indicate that the only points of similarity between the Yorkshire *Marsupites* chalk and that in southern counties is that it is divided into the *Marsupites*-band above and the *Uintacrinus*-band below. The fact that *Actinocamax granulatus* occurs in the *Marsupites*-band does not bring this sub-zone into line with southern sections, for its presence here is not a restricted one, being but an extension of its range from the *Micraster cor-anguinum*-zone and the *Uintacrinus*-band, to the zone of *Actinocamax quadratus*.

It would be difficult to imagine a less conventional *Marsupites*-fauna, for *Micraster cor-anguinum*, *Echinoconus conicus*, the nipple-shaped head of *Bourgueticrinus*, *Ammonites leptophyllus*, *Terebratulina rowei*, *Rhynchonella plicatilis*, *Crania parisiensis*, *Thecidea wetherelli*, *Pecten cretosus*, *Spondylus spinosus*, *Neithea quinquecostata*, *Ostrea hippopodium*, *O. semiplana*, *O. normaniana*, *O. lateralis*, and *Caryophyllia cylindracea*, are entirely wanting in our collection; while vertebrate remains, *Echinocorys vulgaris*, *Lima hoperi*, *Spondylus latus*, *Spondylus dutempleanus*, *Parasmilia*, Bryozoa, and *Serpula* are notably rare.

The points in which this section in some measure coincides with others in the south are that *Zeuglopleurus rowei* and the barrel-shaped columnar of *Bourgueticrinus* are found in both divisions of the zone; that *Rhynchonella reedensis* is the commonest brachiopod; and that *Ostrea vesicularis* and *Ostrea wegmanniana* are found in beds, as at Brighton and Margate.

So badly preserved are the examples of *Echinocorys vulgaris* in this zone that not only have we not included this usually important guide-fossil in the zonal summary, but we have not even ventured to place it among the associated guide-fossils. We found one sub-pyramidal form in the *Marsupites*-band, but it would be impossible to suggest that the distinctive shape-variation is, as in all southern sections, characteristic of this zone in Yorkshire. Nearly all the examples of *Echinocorys* in these upper zones have the apex crushed or sheared off. Many of these urchins lie in the plane of a marl-band, and the impression is given that movements in the rock along these lines of diminished resistance, have ground off the top of the echinoderm.

In all probability we have made a mistake in calling the distinctive form of the *Marsupites*-zone in the south the var.

* *Op. cit.* Dorset, p. 54.
† *Op. cit.* Kent and Sussex, p. 296.

pyramidatus. The true *Echinocorys pyramidatus* is Portlock's* species from the *mucronata*-chalk, and is both larger and different in shape from the zonal variety under discussion.

Zeuglopleurus rowei,† always a rare fossil, was represented by three examples of medium size, one in the base of the *Marsupites*-band, and the other two at the top of the *Uintacrinus*-band. It was not found in Sussex or Dorset, so this is only the second record of its occurrence in this zone.

The other regular echinids consist of spines of *Cidaris hirudo*, *Cidaris sceptrifera*, and *Cidaris subvesiculosa*, but none are really common. The single examples of *Salenia granulosa* and *Ophiura* were found at the top of the *Uintacrinus*-band. The former are even smaller than its dwarfed prototype in the *Terebratulina gracilis*-zone (p. 242), for it measured but $2\frac{1}{2}$ mm. in diameter.

Infulaster rostratus at this horizon presents a marked numerical contrast to its profusion in the chalk of *Micraster cor-anguinum*, for we only record two examples in each division of the zone; so that it is even less common than in the *quadratus*-chalk. *Cardiaster ananchytis*, so abundant in the zone immediately above, figures in our list as a solitary example from the middle of the *Marsupites*-band.

Bourgueticrinus is so comparatively rare, and so devoid of usefulness as a guide-fossil, that it merits a further statement on the subject. Even columnars are of infrequent occurrence in this zone, the only head being found in the *Uintacrinus*-band, and resembling the dwarfed form which we found in the *Micraster cor-anguinum*-zone south of High Stacks. The nipple-shaped head was not found, and the barrel-shaped columnars consisted of but two examples.

With the exception of *Belemnitella mucronata* the cephalpoda of the White Chalk are proverbially erratic in their distribution in England, and those of the Yorkshire coast are no exception to the rule. That *Ammonites leptophyllus* should be absent is no new thing, for it is equally wanting in our lists for the same zone in Dorset. Those who are interested in the distribution of this group can refer to the summary in the Dorset paper‡ which deals with the counties of Kent, Sussex, and Dorset.

The distribution of *Actinocamax* on the Yorkshire coast is quite remarkable, and extends our knowledge of this interesting but inconstant fossil in no slight degree. We have already traced it, on the authority of Mr. J. R. Mortimer, in the flinty chalk of the *Micraster cor-anguinum*-zone at Fimber, and have followed through the 160 ft. of flintless chalk belonging to this zone, and now we find that it is equally common

* Portlock. Report on Londonderry, p. 355, 1843.
† *Op. cit.* Kent and Sussex, pp. 300, 353, 354.
‡ Dorset, pp. 53, 54.

in both divisions of the *Marsupites* zone. There is some tendency for it to run in bands in all the zones which yield it. In Thanet this belemnite is confined to the *Marsupites*-band, while in Sussex* it is found at the same level, chiefly in the upper 20 ft., and ranges up into the base of the *Actinocamax quadratus*-chalk, occurring sporadically only above the base of the zone, but extending as high as 150 ft. In Dorset† it is rare, and only occurs at the base of the *Actinocamax quadratus*-zone. It will be seen, therefore, that the distribution of *Actinocamax granulatus* in Yorkshire differs from that of any section of this zone which we have previously recorded. Anyone collecting a series of belemnites on this coast in strict zonal order will at once be struck with the progressive deepening of the alveolar cavity compared with examples from the zone of *Micraster cor-anguinum.*

Actinocamax verus is as rare it this zone on the Yorkshire coast as *Actinocamax granulatus* is common. At present we have only a record of two examples in the *Marsupites*-band, and one in that of *Uintacrinus*. This is the more remarkable when we consider that it is relatively commoner in the zones of *Micraster cor-anguinum* and *Actinocamax quadratus*, and when we remember that it is fairly abundant in the *Uintacrinus*-band of Thanet, Sussex,‡ and Salisbury. Its rarity in Yorkshire finds a partial parallel in Hampshire, where it only occurs in the upper part of the *Micraster cor-anguinum*-zone. Probably further collecting will increase the number of examples of this belemnite both on the Yorkshire coast and in inland sections.

Brachiopods, with the exception of *Rhynchonella reedensis*, are poorly represented, for *Terebratulina striata*, *Kingena lima*, *Crania egnabergensis*, and *Terebratula semiglobosa* are quite rare. All are deeply impregnated with iron-oxide, and, especially in the lower part of the zone, so adherent to the matrix that it is impossible to remove them in a perfect state. We only found two examples of *Crania egnabergensis*, one in each division of the zone, though one, a strange exception in this region of shattered shells, was double. Both were small specimens, measuring respectively $4\frac{1}{2} \times 4\frac{1}{2}$, and $3\frac{1}{2} \times 3\frac{1}{2}$ mm. *Kingena lima* was too broken to study its shape-variation, and was mostly of moderate size, though one measured 16×13 mm. *Terebratulina striata* was also dwarfed, the largest only measuring $4\frac{1}{2} \times 3\frac{1}{2}$ mm., and one was only 2 mm. in its short diameter. *Crania parisiensis*, as we have said, was not found at all. *Thecidea wetherelli*, generally fairly common as an adnate form in this zone, was also absent; but we found one large free example, with both valves perfect, and measuring 5×4 mm., at the base

* Kent and Sussex, pp. 297, 343, 348.
† Dorset, p. 57.
‡ Kent and Sussex, pp. 299, 348.

of the *Uintacrinus*-band. This is probably an example of another species, and recently we have found a second apparently identical form at the same horizon at Margate. These are the only two specimens which we have seen. We have already noted the absence of *Rhynchonella plicatilis* in this zone.

Lamellibranchs, if we exclude *Inoceramus cuvieri*, *Ostrea vesicularis*, and *Ostrea wegmanniana*, are rare. At the upper part of the zone we found three examples of *Inoceramus lingua*, but we have not met with it below this level. *Ostrea wegmanniana* is much rarer in the *Uintacrinus*-band than in the upper division of the zone, and has not the tendency to run in bands which is so notable at the higher horizon. *Spondylus latus* and *Spondylus dutempleanus* were represented by single specimens in the *Marsupites*-band, and a solitary example of the latter was found in the *Uintacrinus*-band. A fragment of *Lima hoperi*, generally so common and large at this horizon, is our only record for the zone. We have already noted that *Neithea quinquecostata* and *Pecten cretosus* were not found at this horizon.

No corals were found in the *Marsupites*-band, but two examples of *Parasmilia centralis*, one of *Parasmilia fittoni*, and one of *Parasmilia cylindrica* were obtained in the *Uintacrinus*-band. *Caryophyllia cylindracea*, which we have always regarded as characteristic of this horizon, especially of the *Marsupites*-band, was not found.

Bryozoa are notably rare, *Vincularia disparilis*, *Eschara rimosa*, *Eschara lamarcki*, and *Membranipora* were alone obtained, and the bulk of them belonged to the first species. That the ever-present *Eschara lamarcki* should be represented by a single example is quite without parallel in our experience.

The sponges are neither so numerous nor so interesting as those in the *quadratus*-chalk; but those preserved in iron-oxide are the same as those quoted in the zone immediately above, with the exception of *Ventriculites infundibuliformis* and *Cœloptychium agaricoides*. The calcite sponges are quite a feature of this horizon, though not to the same extent as in the *quadratus*-chalk, and one notices that they become increasingly frequent as one ascends the zone.

Porosphæra again quite fails us as a zonal guide-fossil, for not only is it much smaller than in the South, but it is also rarer. We collected 115 examples in all from this zone. Of these 88 belonged to *Porosphæra globularis*, 7 to *P. globularis* var. *nuciformis*, 10 to *P. pileolus*, and 10 to *P. pileolus* var. *patelliformis*. The last-named all occurred in the *Uintacrinus*-band, and were of proportionately large size. The small percentage of Dr. Hinde's var. *nuciformis*, which has hitherto been wrongly called *P. woodwardi*, is very noteworthy; and the small size of *P. globularis*, which generally reaches such large dimensions as to be diagnostic of the zone, is equally striking.

The largest example measured but 13 mm. in diameter, and the bulk of them range between 2-6 mm.

The rarity of *Serpula* is again quite remarkable, for we only record two examples of *Serpula granulata*, two of *Serpula ilium*, and one of *Serpula fluctuata*. Two long thin forms, one bluntly quadrate, and the other bluntly pentagonal, were found, but we could not determine them. *Serpula plana*, *Serpula ampullacea*, and *Serpula turbinella*, usually so common at this horizon, are wanting in our lists.

Vertebrate remains are surprisingly rare, and we can only record a single tooth of *Lamna appendiculata* in the *Uintacrinus*-band, and one of *Notidanus microdon* in that of *Marsupites*.

Those who would study the fossils of this interesting zone in the light of local faunal variation will find a complete synoptical summary of this chalk in the counties of Kent, Sussex, and Dorset in the paper devoted to the last county.* If all sections of this zone resembled that of Yorkshire, there might be valid reason for giving to both *Marsupites*-band and *Uintacrinus*-band a full zonal value, instead of making them but divisions of one zone. The Yorkshire fauna, however, is so peculiar and exceptional that we see no reason to depart from the scheme already formulated in our previous papers.

Zone of Actinocamax quadratus.

(Local equivalent—Zone of Inoceramus lingua.)

Inoceramus lingua *Cardiaster ananchytis* *Actinocamax granulatus* *Hamites* sp. *Rhynchonella reedensis* *Ostrea wegmanniana* Calcite sponges *Ventriculites infundibuliformis* *Cœloptychium agaricoides*	Found throughout the zone. 177 ft. exposed at Sewerby Cliff.
Scaphites binodosus	Found only inland, and above the 177 ft. level.

Associated guide-fossils: *Cardiaster pillula*, *Echinocorys vulgaris*, *Cidaris hirudo*, *Scaphites inflatus*, *Scaphites* sp., and *Avicula tenuicostata*.

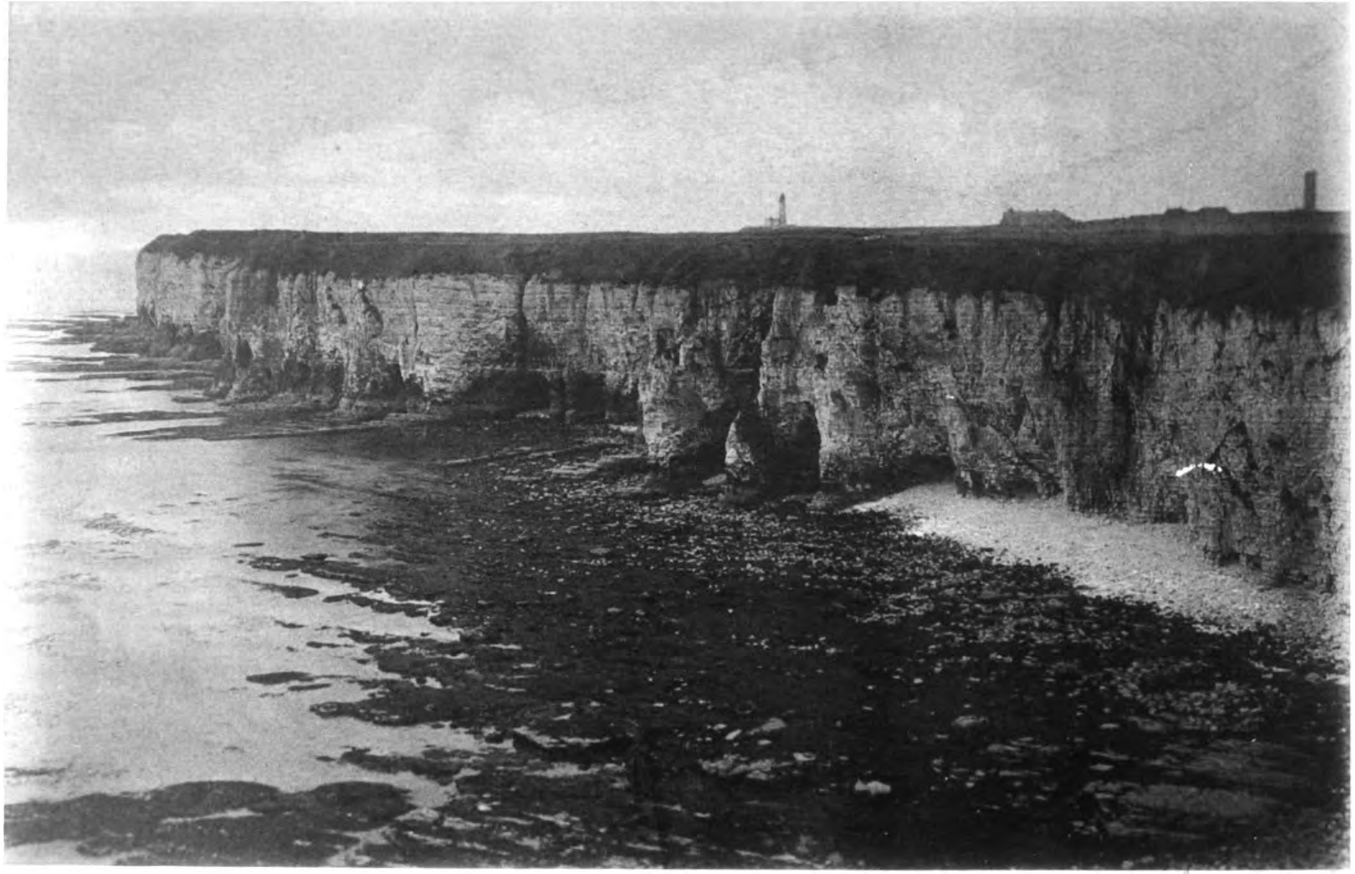
We have already (p. 225) given our reasons for founding a local equivalent zonal title for this chalk, and the position which we have assumed in this matter has the unhesitating support of Mr. Lamplugh, whose knowledge of this coast and its fauna is so

* Dorset, pp. 53-55.

extensive. It may be that in time we shall discover the true *Actinocamax quadratus*, either in the high ground between Bridlington and Driffield, from the chalky drift of Bridlington, or in the drifts of Holderness. That much of the highest chalk has been denuded during the severe conditions of Pre-glacial and Glacial times, we have abundant reason to know, and there is the statement that at Hornsea the well-sinkers passed through 800 ft. of flintless chalk. This last point seems to have an element of doubt about it, and those who are interested in the subject are referred to Mr. Lamplugh's paper,* where the question is discussed in some detail. Mr. W. H. Crofts, of Hull, who is in touch with all details relating to boring in this area, has promised to submit all belemnites found in the future for our inspection, so that we may possibly arrive at some definite conclusion at no distant date. It has already been mentioned that *Belemnitella mucronata* has been obtained from the boulder-clay in Holderness, along with several other chalk fossils which we have not yet examined; but it is impossible at present to say whether these fossils have been derived from the buried floor of chalk in Holderness, or whether they have been transported from some distant locality.

We have 177 ft. of *quadratus*-chalk displayed in Sewerby Cliffs, and it is well known that certain fossils, such as *Scaphites*, *Micraster*, and to a less extent, *Hamites*, which are not found at Sewerby, are obtained in the quarries on the high ground north-west of the coast. It is clear, therefore, that these quarries occupy a higher level in the *quadratus*-chalk than the incomplete exposure of this zone on the coast. If confirmatory evidence were needed we have it in *Actinocamax granulatus*, which shows a sensibly deeper and more quadrate alveolus in the highest pits than is exhibited in the examples yielded by Sewerby Cliffs. On this important question Mr. Lamplugh writes†: "But it is almost certain, on both stratigraphical and palæontological considerations that the chalk on the rising ground south-west of Bridlington comprises a considerable thickness of higher beds than the uppermost layers represented in the cliff-sections; and though the depth of these higher strata has not yet been accurately determined, I believe that they cannot fall below 100 ft., and not improbably are much thicker." We entirely share this writer's views, and have based our own calculations for the range of *Actinocamax granulatus* on the assumption that we have at least 150 ft. of chalk higher than that of Sewerby Cliff; and we are of opinion that we might even add another 100 ft. without taking an exaggerated view of the thickness of the *quadratus*-chalk which has been spared by the forces fo denudation. Great though the thickness of such a zone would be, it would not be

* G. W. Lamplugh, *op. cit.*, Part I, p. 71.
† G. W. Lamplugh, *op. cit.*, Part I, p. 68.



BREIL HEAD, WITH CRADLE HEAD IN DISTANCE.

unwarrantable as a supposition, for in the vertical and compressed chalk between Black Rock and Arish Mell, Dorset, we have recorded a thickness for this zone of 354 ft.; and the considerable thickness of the zones in Yorkshire, from the beds of *Terebratulina gracilis* upwards, certainly does not militate against the idea of an unusually thick *quadratus*-chalk. That one of the highest zones may have a great thickness is proved by the enormous depth of the zone of *Belemnitella mucronata* at Norwich, and by the measurement of 250 ft. for an incomplete section of the same zone at Ballard Head and Studland Bay. It may be well to mention that we do not expect to find any exposure of the zone of *Belemnitella mucronata* in the Bridlington area.

The question of the zonal title for the *quadratus*-chalk in England has long been a vexed one, and we have set forth our views on this point in the Kent and Sussex paper,* and in that on Dorset†. The chalk of this horizon in Yorkshire does not remove our difficulties, but rather adds to them, for the alternative name-fossil, *Cardiaster pillula*, is so rare as to be useless as a zonal guide. We now pass to the consideration of this zone as shewn in the area under discussion.

Inoceramus lingua is so abundant, and so uniformly distributed, that we feel justified in giving it the prominent position of local equivalent name-fossil for this zone in Yorkshire. A figure of this interesting lamellibranch will be found in Goldfuss, Petrefacta Germanica, Pl. CX, Fig. 5. Like many other fossils this lamellibranch has a tendency to run in bands, and for that reason we may fail to find it in one or two quarries. Still, the fact remains that it is wonderfully uniform in its distribution, that it often occurs in vast numbers, and that it is a very easy fossil to determine in the field.

The chief interest in this zone probably centres around *Actinocamax granulatus*, which is quite an abundant fossil, and usually well preserved, as the chalk at this horizon is generally softer and more marly, though we should hardly feel justified in employing the adjective "tendre," used by Dr. Barrois in referring to the upper beds of the flintless chalk. Even at Sewerby Cliff the progressive deepening of the alveolar cavity is obvious, and it becomes more marked in the higher chalk south-west of Bridlington. Coupled with an increased depth of the alveolar cavity is a tendency for the section of that depression to be more quadrate, and towards an increase in the granulation of the guard. Still, as we have said before, we have yet to see an example of the true *Actinocamax quadratus* collected in this area, either by ourselves or by Yorkshire geologists.

Among the novel facts in the distribution of *Actinocamax* in

* *Op. cit.*, pp. 345, 346.
† *Op. cit.*, pp. 58, 59.

Yorkshire none is more interesting than the occurrence of *Actinocamax verus* in this zone. Certainly in no English section have we heard of this species being found at such a high horizon. Its range at Sewerby Cliff is from the base of the zone to the highest accessible level at Cliff End. As yet we have not found it in the higher chalk in inland sections. In the Mortimer Museum are examples from Townside Fall, a quarter of a mile north-east of Driffield, and also from Beverley. The zone is not indicated in these specimens.

Cardiaster ananchytis runs in bands in this zone, and is almost as abundant as *Inoceramus lingua*. We have not yet secured a really perfect specimen, for like most large fossils in this chalk, it is generally crushed. In size it usually resembles that of the same form in the *mucronata*-chalk, though the largest examples are greater than those from the higher zone. The largest examples at Sewerby are found near the top of the exposure, and we obtained one enormous specimen, with the posterior end missing, which measured 80 mm. in its transverse diameter. This is the only urchin, save perhaps the rare and large forms of *Micraster cor-bovis*, which rivals the dimensions of *Holaster placenta*. From such material as we collected we are of opinion that the shape of this echinid is similar to that of the same species in the *mucronata*-zone. We brought away 23 examples of this urchin, and were struck by the fact that no less than 15 of these were covered with their spines, which sometimes formed quite a thick felting over them. This we attribute to the marly nature of the chalk, for this same preservation of spines is noticed in *Holaster trecensis* of the Chalk Marl at Dover, and in the Echinoderms of the marly *Marsupites*-chalk at Brighton. This wholesale preservation of spines doubtless accounts for the absence of adnate forms on the tests. We have already noted the occurrence of this species in the *Micraster cor-anguinum*-zone, and in that of *Marsupites*. In Yorkshire, therefore, we have a known range for this fossil of about 640 ft.

Rhynchonella reedensis is incomparably the commonest brachiopod in this zone, as may be inferred from the fact that we collected no less than 75 examples. It is much better preserved than in the lower zones, and notably larger. Its presence in quantity is quite an index of horizon. The same remark applies to *Ostrea wegmanniana*, which occurs in thick bands, mingled with *Ostrea vesicularis*. Perfect specimens are rare, but one finds them literally by the hundred in certain quarries.

The sponges of Flamborough Head have long been famous, and Dr. Barrois* points out the affinity which they, together with *Inoceramus lingua* and *Scaphites binodosus*, establish between this zone in Yorkshire and the *quadratus*-chalk of North-West Germany.

* *Op. cit.* pp. 198, 199.

Unfortunately the spicular structure of our Flamborough sponges is not retained, so that identification with the beautifully preserved forms of Germany is difficult. We had intended to give a list of sponges collected in this zone, but the difficulties of determination were so great that we have decided to leave them out of our lists altogether. Later on, when our collection is more complete, we shall be able to compare them with the recently acquired series from Hanover at the British Museum (Nat. Hist.).* Mr. Lamplugh has a fine series of these sponges, collected mainly to illustrate the methods of growth, and he agrees with us that when this large sponge fauna can be properly named, use may possibly be made of the various species to mark certain levels in this zone. We append a list of the Flamborough sponges from Dr. Hinde's monograph. They are not referred to any definite zone, but we know from experience that they are probably all derived from the *quadratus*-chalk, where alone they are really abundant.

Pachastrella convoluta
Seliscothon planus
Seliscothon explanatus
Verruculina pustulosa
Verruculina milliaris
Scytalia fastigiata
Scytalia radiciformis
Scylalia terebrata
Pachinion scriptum
Heterostinia obliqua
Isorhaphina texta
Phymatella reticulata
Verruculina astrea
Verruculina convoluta
Verruculina plicata
Verruculina reussii
Verruculina papillata
Siphonia koenigi
Bolospongia globata
Bolospongia constricta
Turonia variabilis
Tethyopsis cretaceus
Jereica clava

The Flamborough sponges are very abundant, and are best seen on the scars, chiefly in the position of the letters "rby," in "Sewerby Rocks," on the 6-inch map, sheet 128. It is of interest to note that the sponges preserved in iron-oxide are equally common, and that the bulk of them, which we generally find throughout the White Chalk of the South of England, are never calcified. It would probably be correct to say that all these calcified sponges are peculiar to this district, so far as England is concerned, with the exception of *Siphonia Kõnigi*, *Stichophyma tumidum*, *Pachinion scriptum*, and *Heterostinia obliqua*. The process of mineralisation is curious. One often finds a calcified and an iron-oxide sponge in actual contact, the mineralisation of each being quite perfect in their respective states. At other times, the calcite sponges are found in every state of transition in their degree and method of mineralisation, some being completely calcified, save for an iron-oxide root, and

* See also G. J. Hinde, Cat. Fossil Sponges of Geol. Dep. Brit. Museum, 1883.

others quite rotten with oxide. The latter is probably a purely secondary replacement. More rarely, one finds one of the common hexactinellid sponges, such as *Ventriculites*, with an imperfect attempt at calcification. Roughly speaking, the lithistids are preserved in calcite, and the hexactinellids in iron-oxide.

We have used the term calcite sponges because they are in the main soluble in acid. They have usually been described as silicified, but this observation renders such a theory doubtful. Professor H. E. Armstrong kindly examined some of the characteristic lithistids for us, and he says that the material in which they are preserved is calcite.

But apart from the calcite sponges, there are certain of the usual iron-oxide forms which are here of high zonal value. The chief of these is *Ventriculites infundibuliformis*, which is so abundant and evenly distributed, both on the coast and in the quarries in the higher chalk, and is, moreover, so readily recognised in the field, that it assumes a prominent position as a guide-fossil. Indeed, but for the fact that it is a characteristic fossil of the *mucronata*-chalk of Norwich, it would have strong claims for the position of local equivalent name-fossil for this zone in Yorkshire. *Cœloptychium agaricoides*, though not abundant, is restricted to this zone, and the same may be said, though in a less degree, of *Porochonia simplex*, which is of more frequent occurrence. Magnificent examples of both the calcite and iron-oxide sponges are to be seen in the Mortimer Museum at Driffield, as well as in the British Museum (Nat. Hist.) and the Museum of Practical Geology.

Another of the interesting features in this zone in Yorkshire is the presence of *Scaphites* and *Hamites*. Both these forms, especially the former, run in bands, and are distinctly restricted to the highest beds. Dr. Barrois* draws attention to *Scaphites binodosus*, and Professor Blake† to two other species of *Scaphites*, and one of *Hamites*.

Hamites is found much lower in the zone than *Scaphites*, and we record it as low as 40 ft. above the junction of this zone with the *Marsupites*-band in Sewerby Cliff; but it is commoner at the highest part of the chalk exposed at Sewerby Cliff End, and we find it on the scars at the spot which the cartographer, with a sense of humour usually lacking in these severe publications, has called the "Muscle Beds." We have also recorded it for many of the pits in the higher chalk of this zone. How high it ranges we know not yet, as our examination of the higher beds has been of a purely tentative nature, but we have obtained it in some of the highest quarries in this area. We have been unable to

* *Op. cit.*, p. 199.

† J. F. Blake. "On the Chalk of Yorkshire." *Proc. Geol. Assoc.*, Vol. v, No. 5, Jan. 1878.

PARAMOUDRA IN NORTH SEA LANDING, EAST SIDE.

ascertain the specific name of this cephalopod. Probably there is more than one species.

Scaphites binodosus,* when we happen to find a quarry in the higher chalk in which the Scaphite-bed is developed, is a really common fossil. We have noted it in Pits 20, 21, 27, and 30. It is interesting to note that while it is found in No. 30, on the 100-ft. contour-line, it has not been found in the neighbouring quarry, No. 29, which is lower by 50 ft. This indicates the local nature of the Scaphite-band, and at the same time illustrates the useful nature of this fossil as a guide to the higher chalk. Hitherto *Scaphites* has not been found *in situ* in the 177 ft. of the zone displayed in Sewerby Cliff, either by ourselves or by local collectors; but Mr. Lamplugh obtained a specimen when he was excavating in the old buried cliff at Cliff End, Sewerby. This was on a rolled boulder, and we had the good fortune to find another example, also on a boulder, near the same situation. Whether our specimen was derived from the present cliff, or from one of the boulders in the drift, or the old beach, we know not. We incline to the latter supposition.

In addition to the species already mentioned we find *Scaphites inflatus*, and there are probably two, if not three, species in addition. These we have been unable to determine. Mr. Stather has a fine series of these fossils in his collection, and some beautiful examples are in the Mortimer Museum. A reference to the latter collection would probably give us other inland localities where this genus occurs.

Cardiaster pillula is, as we have before indicated, a rare fossil. We only collected eleven examples in all, five of which came from Sewerby Cliff, and all were of rather small size. We found it both at the base and the top of the Sewerby section, and obtained it at pits 31 and 32 at Carnaby. None of the other quarries yielded it. How rare this usually abundant echinid is on the coast may be inferred from the fact that it had never been found there by local collectors, though Mr. Stather had collected it at Carnaby.

Echinocorys vulgaris is rather common, but would be considered rare in comparison with the profusion with which it occurs in the south. On the whole it is a large race. We brought away thirty examples from this zone, four of which had thin tests. Uncrushed specimens are very rare, and consequently shape-variations are difficult to establish. We secured one dwarfed form from the base of the zone at Sewerby, two very flat dome-shaped examples from the same locality, and one very large and tall, dome-shaped individual from Ruston Parva. The chief shape-variation would appear to be an ovate-gibbous form, such as we see at the junction of this zone with the *Marsupites*-band in the South. Bryozoa and other

* F. A. Roemer, Verst. Norddeutschen Kreide. Pl XIII, Fig. 6. 1840-41.

adnate forms are rare, and adherent spines much more common than usual. There is a band of this urchin at the base of the zone at Sewerby.

Cidaris hirudo is the dominant regular echinid in this zone, and its spines are fairly common. We only found five spines of *Cidaris sceptrifera*, all at the base of the zone, and two of *Cidaris subvesiculosa*. Four examples of *Cyphosoma corollare* constitute our record for this genus, and *Salenia*, usually somewhat abundant at this horizon, was not found at all.

Bourgueticrinus, usually both abundant and highly diagnostic, is here notably rare. The columnars found, though remarkably small, were fairly characteristic; but we did not obtain a single head of this crinoid. Throughout the whole coast we note that this genus is not only dwarfed, but quite useless as a zonal guide-fossil.

Micraster is one of the curiosities of the zone, and is of very local occurrence. We only found it at the higher pit at Bessingby Hill, No. 30, and even there it is by no means common, and generally crushed. Mr. Lamplugh has a good series of this urchin from Bessingby, and examination of these examples shew that it is a carinate form, with deep anteal sulcus and notch, and with labrum near the anterior margin—a shape-variation which we generally associate with the zone of *Belemnitella mucronata*.

Infulaster rostratus is, curiously enough, commoner at this horizon than in the *Marsupites*-zone. We collected eight examples, all from Sewerby Cliff, but as yet have not found it in the quarries. Doubtless it exists there, and it will be an interesting quest for Yorkshire geologists to extend the already immense range of this echinid. We have already mentioned (p. 250) that it extends from the zone of *Micraster cor-testudinarium* to the highest *quadratus*-chalk exposed on the coast at Sewerby, giving thus a range of nearly 700 ft.

Avicula tenuicostata is another fossil new to our experience in this zone. Professor Blake* refers this form to *Avicula tenuicostata*, Roemer† and we are ourselves clear as to the correctness of this determination. The collections of Mr. Mortimer and Mr. Stather contain some fine examples. We found five specimens in the lower two-thirds of the Sewerby section, and several other fragments were obtained in the quarries. We do not know how high this fossil extends in inland sections. But for its comparative rarity it would be a most useful guide-fossil, as it is here rigidly confined to the *quadratus*-chalk.

As some doubt has been expressed concerning the determination of this *Avicula*, we have, through the agency of

* *Op. cit.*, p. 259.
† *Op. cit.* Pl. viii, Fig. 15.

Dr. F. L. Kitchin, submitted examples to Dr. Johannes Böhm, of Berlin, who has no hesitation in referring it to Roemer's species. He says that Roemer's Lower Chalk of Lindner Berge, near Hanover, is really *quadratus*-chalk, as shewn by H. Credner (Geogn. Karte d. Umgegend v. Hannover, 1865). Roemer called it *A. lineata* first (Kredegeb., p. 64), and changed the name to *A. tenuicostata* on the plate. The name *lineata* was preoccupied, so *tenuicostata* stands as the correct specific title. Dr. Böhm thinks that this shell is rather rare in North Germany. We are able to give two other records of its occurrence in England. These are from Coddenham in Suffolk, and from Salisbury. From the former locality there are four examples in the Museum of Practical Geology, Jermyn Street (P. 1875, P. 1882, P. 1883, P. 1884), and through the kindness of Mr. E. T. Newton and Dr. Kitchin we have been able to examine them. The only characteristic zonal fossil associated with them is *Echinocorys*, and on inspection of this fossil proved that it was derived from the zone of *Actinocamax quadratus*. Dr. Kitchin has no doubt as to the determination both of these and the Yorkshire specimens. The small series from Salisbury was found by Dr. Blackmore in the lower part of the *quadratus*-chalk, and a specimen which he has given us proves that these three localities have all yielded the same species. We have given these records in some detail as they indicate that *Avicula tenuicostata*, though rare, is essentially restricted to the *quadratus*-chalk. Mr. Charles Griffith, however, has not found it in Hampshire, nor did we find it in Dorset or Sussex.

In the Mortimer Museum at Driffield is a slab from Sewerby Cliff containing six specimens, and others came from Turner's Brickyard, Driffield, and from Life Hill, Sledmere. In spite of the slab from Sewerby this shell is certainly not common in Yorkshire. It has only been found in the *quadratus*-chalk.

The vertebrates contained in our list consist of two vertebræ of a Mosasauroid, and a single tooth of *Lamna appendiculata*. Never in our experience have we found so few teeth in this zone.

The cephalopoda furnish us with some rare fossils. Mr. Stather has a small Ammonite from the base of the *quadratus*-chalk at Judge's Pit, Beverley, and he and Mr. Lamplugh each possess another from the scars below Sewerby Park. The Beverley specimen is about four inches in diameter, and Mr. Crick thinks that it is closely related to *Ammonites pseudo-gardeni*, Schlüter, from the "Haupt-quadraten schichten," Dülmen, Westphalia.

Two examples of *Nautilus* have been found by Mr. Stather on the Sewerby scars, below the main sponge bed, and one by Mr. Lamplugh in much the same situation. We have not been able to ascertain the name of this species. In any case, *Nautilus* is a rare form, and for this reason useless as a guide-

fossil, though it is found in no other zone on this coast. We obtained a small *Aptychus* in the large quarry (No. 29) at Bessingby Hill. Only the smooth internal surface is exposed, and as it is in chalk of stony hardness it is quite impossible to clean it sufficiently for determination.

Mr. Lamplugh found an example of *Aptychus* in Bessingby Pit (No. 30), and there are no less than thirteen specimens in the Mortimer Museum, all with the smooth surface upwards. They were obtained from Turner's Brickyard, Driffield, and from a pit half-way between Wetwang and Sledmere. Those from the former quarry were associated with an abundance of the characteristic calcite sponges of the *quadratus*-zone, so that the horizon of this locality is fairly clear.

The only gasteropod which we have seen is a species of *Pleurotomaria* found by Mr. Lamplugh on the scars opposite Sewerby House. It was, therefore, near the upper limit of the section.

There is a fine series of this gasteropod in the Mortimer Museum, and the localities given are Burdale, Pluckham, Thixendale, Bessingby, Wharram, Beverley, Gills, Ashlam Wold, Raisthorpe, Life Hill, Wharram Percy, Driffield, Beverley Westwood, Uncleby Stook, and Hanging Grimston Wold. How many of these quarries exhibit sections of the *quadratus*-chalk we know not, but we are aware that this zone is exposed at Bessingby, Beverley, Life Hill, and Driffield.

Brachiopods, with the exception of *Rhynchonella reedensis*, are not common. Though we collected seventy-five examples of this fossil from this horizon, only six were well preserved. This gives some idea of the way in which shells are crushed in this the softest and least disturbed bed in the Yorkshire Chalk. Not only is *Rhynchonella reedensis* much commoner at this horizon than in any of the other zones, but it is much larger. The largest examples are as much as 13 mm. in their widest diameter, while the largest from the *Marsupites*-zone do not run to more than $10\frac{1}{2}$ mm. *Crania egnabergensis* is rare and notably small, the largest example measuring $4\frac{1}{2} \times 4\frac{1}{2}$ mm. *Kingena lima* is rather rare, of moderate dimensions, and too broken to make out any characteristic zonal shape-variation. The specimens vary from 7 to 14 mm. in diameter. *Terebratula semiglobosa*, as in all save the two lowest zones, is a stunted form, and its longest diameter in this zone varied between 10 and 17 mm. *Terebratulina striata* is also small and rather rare, one example measuring 14 mm., but the bulk of them not exceeding 7 mm. in long diameter. *Rhynchonella limbata* appears as a solitary record in our list.

Lamellibranchs are also poorly represented, for *Pecten cretosus*, *Spondylus latus*, *Spondylus dutempleanus*, and *Lima hoperi* are all very rare. With the exception of the two oysters already

Photo. by Shores, Bridlington.

SELWICK BAY, FROM THE NORTH.

mentioned, the genus *Ostrea* is quite unrepresented in our collection. We found a narrow and highly ornamented *Inoceramus*, 18 in. long, in Sewerby Cliff. Whether this be a very full-grown example of *Inoceramus lingua*, or another and possibly new species, we know not. From the same locality we obtained a large and broad example of this genus (p. 196), as well as two very small forms, with fine horizontal striæ; but neither of these could we determine.

Corals are usually quite abundant in this zone, especially *Cœlosmilia laxa;* but our list contains only two examples of this guide-fossil, and three of *Axogaster cretacea.* This is the only section of *quadratus*-chalk in which the former has not been both abundant and significant of horizon, and it is without exception the poorest exposure in this zone for corals that we have ever examined. We found no corals in the quarries.

Bryozoa are, as usual, a disappointment in Yorkshire, only eleven examples in all being collected, chiefly of *Vincularia disparilis.* As a rule this zone, especially at the base, is crowded with these beautiful forms. The characteristic *Cribrilina** of this zone, which is abundant in Sussex, Dorset, and Wiltshire, is not found in this area.

This is also in all southern sections one of the richest zones for Serpulæ, and yet we can only record two examples of *Serpula turbinella* and one of *Serpula ampullacea.* Indeed, the latter is our solitary record of this species for the whole coast.

As in all the zones hitherto discussed, *Porosphæra* is quite useless as an index of horizon. It is abundant, for we collected 181 examples, of which no less that 166 belonged to *Porosphæra globularis.* As in the two zones immediately below, the size of this sponge is much less than that in the south, the largest example only measuring 15 mm. in diameter, 100 ranging between 2·5 mm. and 6 mm., 56 between 7—9 mm. and 24 between 10—13 m.m. But perhaps the most notable deviation from the usual distribution in southern counties is found in the small numbers of *Porosphæra globularis* var. *nuciformis*, Hinde—the form which has hitherto been called *Porosphæra woodwardi.* That we could only collect eight small examples is in itself sufficient evidence of a departure from its normal abundance in this zone in the South, where this form reaches its maximum numerical development, and where a long and pointed shape-variation is diagnostic of horizon. *Porosphæra pileolus* was represented by seven very small examples, four being of the common thimble shape, and three belonging to the var. *patelliformis*, Hinde.

A flintless *quadratus*-chalk containing no true *Actinocamax*

* *Op. cit.*, Kent and Sussex, p. 345.

quadratus in an estimated thickness of some 400 feet, and exhibiting an altogether unexampled scarcity of *Cardiaster pillula*, is in itself a sufficiently noteworthy condition, especially when it is coupled with a complete absence of the characteristic head of *Bourgueticrinus*, *Ammonites leptophyllus*, *Rhynchonella plicatilis*, *Terebratulina rowei*, *Spondylus spinosus*, *Neithea quinquecostata*, and *Ostrea lateralis*, together with a conspicuous rarity of *Rhynchonella limbata*, *Terebratulina striata*, *Kingena lima*, *Crania parisiensis*, *Pecten cretosus*, corals, and bryozoa. But add to this a profusion of *Inoceramus lingua*, *Cardiaster ananchytis*, *Actinocamax granulatus*, *Ventriculites infundibuliformis*, and calcite sponges, and the existence of such unwonted occurrences as *Infulaster rostratus*, *Scaphites*, *Hamites*, *Actinocamax verus*, *Avicula tenuicostata*, and *Cœloptychium agaricoides*, and we have a picture of a zonal fauna which would be strange even in Yorkshire, and one which is certainly without parallel in the rest of England.

The genus Actinocamax in the Bridlington area.

In the paper on Kent and Sussex* we followed Dr. Barrois in employing the designation of *Actinocamax merceyi* for the large alveolated belemnite of the *Marsupites*-band and the base of the zone of *Actinocamax quadratus*, having taken the precaution of obtaining from this writer named examples of this species. But, even while the paper was in the press, we began to feel doubtful of this determination. To clear up this point Mr. Crick kindly wrote to M. Mayer-Eymar, and obtained from him a typical specimen of *Actinocamax merceyi*. Through the courtesy of Mr. Crick we had an opportunity of examining this belemnite, and it was at once evident that, whatever our English form might be, it was not that of *Actinocamax merceyi*. Mr. Crick considered that it was probably *Actinocamax granulatus*, and to definitely settle this point we wrote to M. de Grossouvre, who sent us examples of *Actinocamax granulatus* from several localities, thus clearing up all possible doubt on the matter. In the Dorset paper† we printed a foot-note setting forth our mistake, and in this latter work we employed the correct title throughout the text.

The coast south of Flamborough Head, together with the high ground between Bridlington and Driffield, affords an unrivalled field for the study of this genus. We have already shown that *Actinocamax granulatus* finds its lowest record, not only in Yorkshire but in England, in the flinty chalk of the base of the *Micraster cor-anguinum* zone at Fimber, and we have

* *Op. cit.*, p. 297.
† *Op. cit.*, p. 13.

traced it through the remainder of this zone, through the *Marsupites*-zone, and through the whole of the 177 ft. of *quadratus*-chalk as exposed at Sewerby. Further than this, we have followed it in the successively higher *quadratus*-chalk of

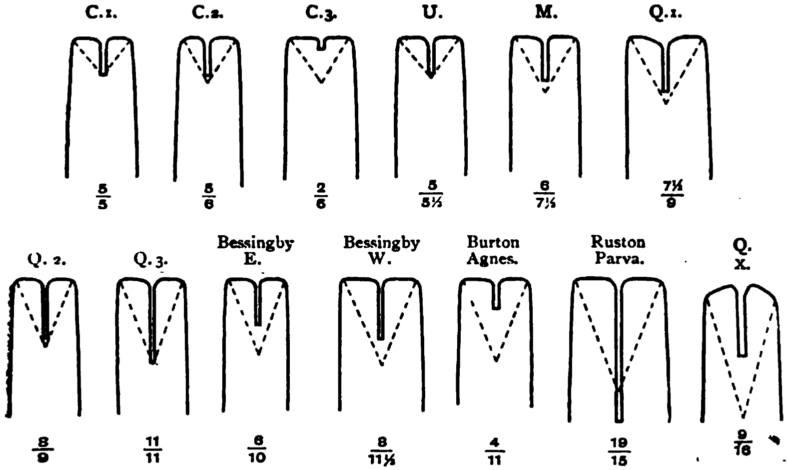


FIG. 12.—DRAWINGS OF ALVEOLAR-ENDS OF *Actinocamax Granulatus*, SHOWING PROGRESSIVE DEEPENING OF THE ALVEOLAR CAVITY AS THE BELEMNITE ASCENDS IN THE ZONES.

(Measurements in millimetres.)

C. 1.—From the base of the *Micraster cor-anguinum*-zone, High Stacks.
C. 2.—From the *Micraster cor-anguinum*-zone, between High Stacks and South Sea Landing.
C. 3.—From the upper part of the *Micraster cor-anguinum*-zone, west of South Sea Landing.
U.—From *Uintacrinus*-band, between South Sea Landing and and Dane's Dike.
M.—From *Marsupites*-band, west of Dane's Dike.
Q. 1.—From *quadratus*-zone, Sewerby Cliff.
Q. 2.—From *quadratus*-zone, „ „
Q. 3.—From *quadratus*-zone, „ „
Bessingby E.—From *quadratus*-zone, East Bessingby.
Bessingby W.—From *quadratus*-zone, West Bessingby.
Burton Agnes.—From *quadratus*-zone at Burton Agnes.
Ruston Parva.—From *quadratus*-zone at Ruston Parva.
Q. x.—Typical example of *Actinocamax quadratus* from the *quadratus*-zone of Harnham, Salisbury. This specimen shows the deep alveolus of the true *quadratus* form, and the cross-section of that cavity is of the typical quadrangular shape.

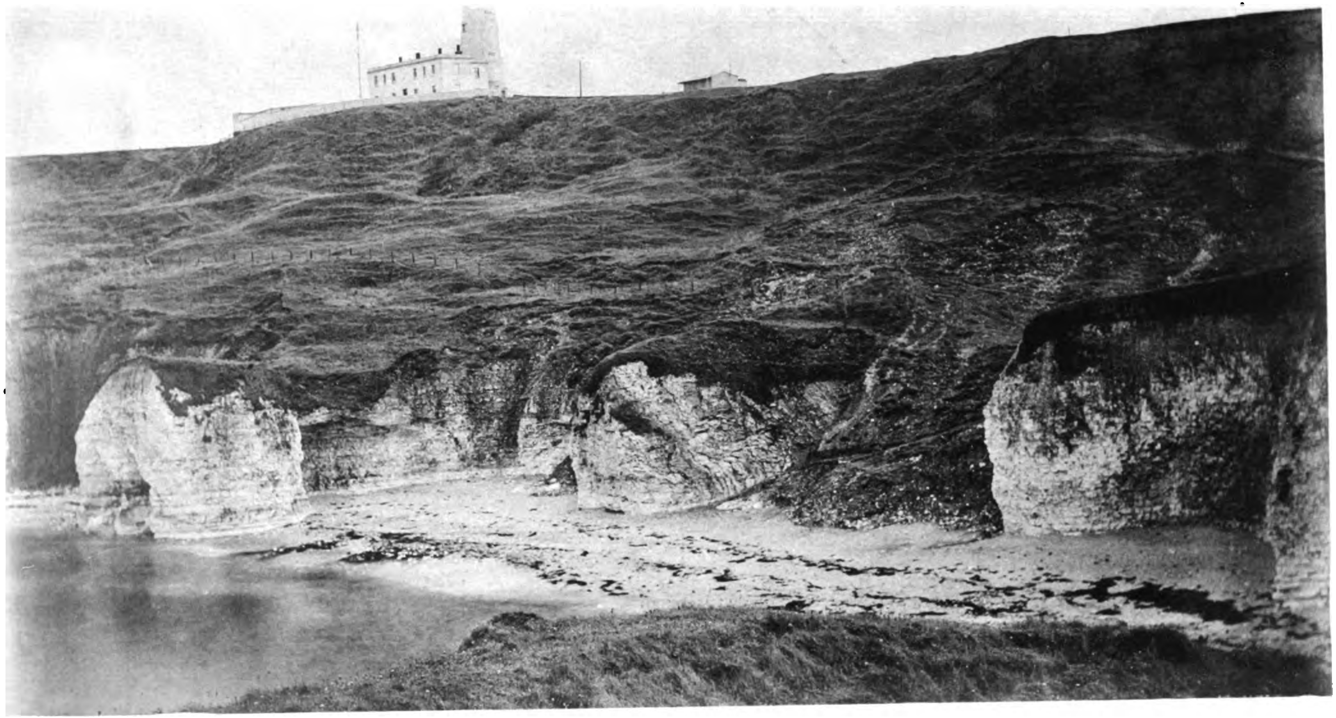
Bessingby, Carnaby, Burton Agnes, and Ruston Parva. We have thus demonstrated in Yorkshire an unbroken range for this species of approximately 800 ft., a thickness of chalk five times greater than that recorded in Sussex, which has hitherto supplied us with its maximum range in this zone. And throughout the

whole of this great thickness of chalk we can trace, step by step, the slow evolution of this species. The whole of the English Chalk fails to show so extensive and continuous a range for a belemnite as this. If ever we had the chance of following out the evolution of a cephalopod it is here. We have shown in the Dorset paper* how we can, by piecing together the evidence of the distribution of this genus in the South of England, link up *Actinocamax westphalicus* to *Actinocamax granulatus*, and *Actinocamax granulatus* to *Actinocamax quadratus*. Here we have no tedious search for data in county after county. We have our distribution and evolution in one unbroken section, and the chain of zoological evidence has not a link missing. In Yorkshire we have as yet seen no example of *Actinocamax westphalicus*; but *Actinocamax granulatus*, in the base of the *Micraster cor-anguinum*-zone, supplies us with almost as primitive a type. We could readily have illustrated in Fig. 12 examples with an even shallower alveolar cavity than those shown in the base of the *Micraster cor-anguinum*-zone. A glance at our diagram will demonstrate the continuous deeping of the alveolar cavity as we pass up through the zones, the fossils being arranged as an ascending zonal series, and the numerals C^1, C^2, C^3, indicating the bottom, middle, and top of the *Micraster cor-anguinum* zone, and so on up to that of *Actinocamax quadratus*. Not only does the alveolar cavity deepen, but the cross-section of that depression, when we reach the highest *quadratus*-chalk, shows a definite tendency to leave the ovate shape and become quadrangular. Further, the granulation of the guard, whenever the specimen is well preserved, shows a tendency to increase in like manner as we ascend the zones; so that, when we reach the highest chalk, the ornamentation on the guard is almost as strong as in the true *Actinocamax quadratus*.

To work out the evolution of this species we collected 150 examples from the coast, and from the pits in the higher chalk. The collecting on the coast was rigidly zonal, and all specimens on fallen blocks were left severely alone.

The *Micraster cor-anguinum* series was the most difficult to deal with, as their preservation was so bad, owing to the hard and adherent nature of the chalk. We discarded many specimens in which the outer layer of the guard had stripped off in removal from the rock, but there was abundant evidence to show that the guard was normally marked by faint granulations, for the presence on not a few of the belemnites of *Plicatula*, Bryozoa, and Coral-bases seems to show that they had lain undisturbed and uneroded on the sea-bottom before being covered up. It was reasonable, therefore, to infer that where the granulation was absent, it was not because it had not existed, but because the

* *Op cit.*, pp. 49-51.



THE HEAD OF SELWICK BAY, SHEWING THE POSITION OF THE FAULT.

guard was defective in its outer layer. This definite degree of granulation entirely excluded *Actinocamax westphalicus*, for the guard of this species, in all examples which we have seen, is devoid of ornamentation.

Actinocamax verus is quite a rare fossil on this coast, for the three upper zones have only yielded us a dozen examples. But it certainly makes up for numerical weakness by its extensive distribution, for it has a known vertical range of fully 650 feet. The greatest measured thickness on the coast for a *Uintacrinus*-band yielding *Actinocamax verus* is that of Margate, where it has a thickness of 68 feet, so that the range in Yorkshire is more than nine times as great, though the numerical proportion of the belemnite is insignificant compared with that in the South. We found *Actinocamax verus* in the highest *quadratus*-chalk on the coast, but as yet have not obtained it in the quarries in the still higher beds of this zone. Mr. Mortimer states that he (p. 252) has found it in the flinty chalk of the base of the *Micraster cor-anguinum*-zone at Fimber. It is quite possible that further collecting may extend the already phenomenal range of this belemnite in both directions, and we await with keen anticipation the researches of Yorkshire geologists on this issue. We have already noted that we have no record of the existence of *Actinocamax verus* in the *quadratus*-chalk of the South of England.

Hitherto we have had certain knowledge of but two localities where *Actinocamax verus* is found in the upper part of the *Micraster cor-anguinum*-zone, these being Micheldever in Hampshire, and Northfleet in Kent. Lately, however, we have found it at the same horizon in a pit near the waterworks at Walmer, Kent, and at East Valley Farm, St. Margaret's; but nowhere in England can we find a parallel to its occurrence at Fimber, as recorded by Mr. Mortimer, over 200 feet down in this zone.

This belemnite, when present in the *Marsupites*-zone is generally confined to the *Uintacrinus*-band, as at Margate, Brighton, Ringwould, and Salisbury. It has not yet been found in this zone in Hampshire, or on the Dorset Coast.

The material of *Actinocamax verus* available for study is in Yorkshire so small that we have had no opportunity for ascertaining if this species exhibits any zonal shape variations, as it often does in the southern counties. The few examples which we collected were rather small, but all of them displayed the characteristic wrinkling on the guard.

Vast as the known vertical range of *Actinocamax granulatus* is in Yorkshire, it may yet be extended in both directions. It may be pure speculation, but we have the idea that if the *quadratus*-chalk were 150 ft. thicker we should arrive at that stage in the evolution of *Actinocamax granulatus* which would entitle us to call it *Actinocamax quadratus*. Further, it may yet be found still deeper in the flinty chalk of the base of the *Micraster cor-*

anguinum-zone in inland exposures. The coast offers so few facilities for collecting in the base of this zone that it is almost hopeless to seek it there. It will be interesting to see if such examples have a plain or an ornamented guard, and if their alveolar cavity be shallower than these in the base of the flintless chalk of this zone.

In France *Actinocamax westphalicus* is found as low as the upper part of the *Micraster cor-testudinarium*-zone. We know no section in England so likely as Yorkshire to yield this rare belemnite at such a low horizon. We made eager search for it both at Newcombe and Breil Head, but without success. That we failed to find it is no reason why Yorkshire collectors should not be more fortunate. No examples were found by Mr. Stather and Dr. Walton in the Kirkella Cutting, nor by Mr. Mortimer in the Etton Cutting. Both these excavations have yielded *Micraster præcursor* of the group-form characteristic of the *Micraster cor-testudinarium*-zone, and will therefore be likely localities for this interesting quest.

Hitherto we have only found *Actinocamax westphalicus* from the upper part of the *Micraster cor-anguinum*-zone in the Northfleet area. We know of only one other record of this species in England, namely, from Grays in Essex, and this is in the British Museum (Nat. Hist.), c. 7341. It was found by Mr. F. R. B. Williams. At Northfleet *Actinocamax granulatus*, *Actinocamax westphalicus*, and *Actinocamax verus* are associated, the last named being quite common. Of the larger forms we have 28 examples, and two only of these can be referred to *Actinocamax granulatus.*

We have had the opportunity of examining Mr. Dibley's series of *Actinocamax* from the Gravesend area, wherein the percentage of *Actinocamax granulatus* is somewhat higher, for out of sixteen examples of the larger forms, thirteen belong to *Actinocamax westphalicus* and three to *Actinocamax granulatus.* It will be seen, therefore, that his series closely corresponds with our own in that *Actinocamax westphalicus* is the dominant form. Moreover, as in our own examples of the latter species, the guard is devoid of granulation.

The evidence relating to the distribution and evolution of *Actinocamax granulatus* on this coast once more brings to the front the vexed and ever-present species question. The original and closely-reasoned paper by Mr. de Grossouvre,* and our own slighter investigations in the South of England, clearly demonstrate the progressive deepening of the alveolar cavity in *Actinocamax* as we ascend the zones. Data such as these cannot be ignored; for though this genus reaches at definite zonal levels a sufficiently accentuated degree of variation in its intrinsic characters as to warrant, for purely stratigraphical purposes, a trivial title, the fact remains that these so-called species are but

* A. de Grossouvre. *Bul. Soc. Géol. de France*, 3e série, tome xxvii, p. 129, 1899.

landmarks in the progressive and unbroken evolution of a single, though somewhat plastic genus. We have shewn elsewhere that the zonal shape-variations of *Micraster* and *Echinocorys* can be traced with similar ease and certainty, and it is clear that in the zonal modifications of *Actinocamax* we have an equally trustworthy guide to horizon. So reliable, indeed, are all these fossils in their zonal variations that a glance at one or two specimens in the field is sufficient to fix the age of the chalk in which they occur. More convincing evidence of the validity of zonal geology it would be impossible to conceive; and the interest in these age enduring and plastic groups only deepens when we realise that these all-important guide-fossils are not rigid species occurring at a definite horizon, but merely zonal stages in the slow and almost insensible evolution of a single genus.

In groups such as these, species can only be considered as labels for convenience in description. So long as we regard them merely as such, and deliberately employ them in this manner, no harm will be done; but to elevate these zonal shape-variations to the position of rigid specific entities, is to disregard the obvious teachings of palæozoology. Accurate zonal collecting can alone educe data such as these, and systematic field-work can have no higher commendation than that it has made such deductions possible.

Sheets of the Six-inch Ordnance Survey Maps Employed.

Bridlington, Bessingby, Carnaby, and Boynton . . .	Sheet 146 N.E.
Bridlington, Flamborough, Marton, Buckton, Bempton, and Speeton	Sheet 128 S.W.
Flamborough Head and South Sea Landing . . .	Sheet 129 S.W.
Flamborough Head to Thornwick Bay	Sheet 129 N.W.
Thornwick Bay to Kit Pape's Spot	Sheet 128 N.E.
Speeton Cliffs	Sheet 128 N.W.

Table of Measurements.

Mr. Lamplugh has conclusively shewn that all previous measurements for this coast have been greatly under-estimated. In his paper entitled "Notes on the White Chalk of Yorkshire"* he discusses the whole question, giving detailed measurements from Cliff End, Sewerby, to Common Hole, and comparing them with the estimates of Young and Bird, Phillips, Barrois, and Blake. We checked Mr. Lamplugh's measurements in the flintless chalk, from Cliff End to South Sea Landing, and found that our result was twelve feet less than his. We unreservedly accept his figures from South Sea Landing to High Stacks, and from the latter point to Stottle Bank Nook, though we had not the opportunity

* G. W. Lamplugh, *Proc. Yorks. Geol. and Polyt. Soc*, Vol XIII, Part I 1895.

to check them. In order that a comparison may be made between these two sets of measurements, we append the figures in double column.

THICKNESS OF THE FLINTY AND FLINTLESS CHALK ON THE YORKSHIRE COAST.

	Mr. Lamplugh's measurements. ft. in.		Our measurements. ft. in.	
Sewerby Cliff End to Dane's Dike	239, 4	Flintless Chalk. 558·5 in.	241, 7	Flintless Chalk. 546 ft. 4 in.
Dane's Dike to South Sea Landing	214, 4		200, 0	
South Sea Landing to High Stacks	104, 9		104, 9	
High Stacks to Stottle Bank Nook (76 ft. measured and remainder estimated)		Flinty Chalk 460 ft.	100, 0	Flinty Chalk 555 ft.
Rest of flinty chalk (estimated) .	460, 0		455, 0	
Flintless beds of *Rhynchonella cuvieri*	11, 4		11, 4	
	1,029, 9		1,112, 8	

On page 75* Mr. Lamplugh gives a total thickness for the flintless chalk, south of Flamborough Head, of 650 ft. The extra 100 ft. is obtained by adding the estimated thickness of the higher beds of the *quadratus*-chalk exposed in the area S.W. of Bridlington. We have based our estimate of the same beds at a minimum thickness of 150 ft., so that our respective totals would work out at 1,129 ft. 9 in., and 1,262 ft. 8 in. We have added the thickness of the *Rhynchonella cuvieri*-zone to both totals, as, though it is a flintless bed, it must be taken into consideration in forming an estimate of the depth of the White Chalk. The omission of the 100 ft. between High Stacks and Stottle Bank Nook in Mr. Lamplugh's column of the table is due to the fact that this measurement is included in his total of 460 ft. for the flinty chalk, whereas we prefer to shew it as a separate item in the calculation. It must be clearly understood that, with the exception of the 76 ft. measured between High Stacks and Common Hole by Mr. Lamplugh, and our measured thickness of the *Rhynchonella cuvieri*-zone, all our calculations for the remainder of the flinty chalk are based on estimates and not on direct measurements. We have based our conception of the thickness of the flinty chalk on a careful examination of this generally inaccessible coast; but where zonal junctions are unobtainable, it is impossible to give more than approximate measurements for any given zone. Our estimate for the flinty chalk north of the headland is 82 ft. 11 in. in excess of that given by Mr. Lamplugh. We have purposely omitted the thickness of the Cenomanian series from our calculations, as they do not come within the scope of this paper. Further information on the thickness of the zones of *Rhynchonella cuvieri* and *Terebratulina gracilis* in Lincolnshire and Yorkshire, as well as

* *Op. cit.*, Part I.

The King and Queen Rocks. An example of wave and sub-aerial erosion.

of the Cenomanian beds, may be obtained in Mr. W. Hill's paper (*Op. cit.*).

We now give a summary of the thickness of the various zones, as measured or estimated by us. Dr. Barrois' localisation of the zones, as well as his calculation of their thickness, differs so widely from our own conclusions that we have not made any tabular comparison between them. The reader, however, is referred to page 201 of his monograph, where the whole question is set out in tabular form. Neither Professor Blake nor Mr. Lamplugh has made any attempt to define the zones.

THICKNESS OF THE ZONES ON THE YORKSHIRE COAST.

		ft.	in.
Zone of *Actinocamax quadratus* as exposed at Sewerby Cliff		177	0
Zone of *Marsupites testudinarius.*	*Marsupites*-band, 121 ft. 1 in. *Uintacrinus*-band, 87 ft. 5 in.	208	6
Zone of *Micraster cor-anguinum.*	Flintless chalk, 161 ft. 6in. Flinty chalk, 100 ft.	261	6
Zone of *Micraster cor-testudinarium* (estimated)		120	0
Zone of *Holaster planus*	"	125	0
Zone of *Terebratulina gracilis*	"	210	0
Zone of *Rhynchonella cuvieri*		11	4
Total thickness of White Chalk exposed on the coast		1113	4
Minimum thickness of *quadratus*-chalk, higher than that on the coast S.W. of Bridlington		150	0
		1,263	4

It will be noted that there is a discrepancy of 8 inches between our summary of zonal measurements and those obtained in measuring the coast as a whole. Our estimate of the thickness of the zones in the flinty chalk on the north side of the headland, which we have calculated, but could not measure, may possibly be excessive, though we took every care to avoid such a result. It is true that they are greater than those recorded by us for the zones of *Terebratulina gracilis*, *Holaster planus*, and *Micraster cor-testudinarium* on the southern coast of England, but it must be remembered that our actual measurements of the higher zones on the south side of the headland are also greater than usual (pp. 218, 222, 225). For the convenience of those who are interested in such matters, we summarise the measurements for the same lower series of zones obtained in the southern sections.

	Zone of *Terebratulina gracilis.*	Zone of *Holaster planus.*	Zone of *Micraster cor-testudinarium.*
Kent	161 exposed	34½	56
Sussex	170	48	109·6
Dorset	58	51	113
Devon	156	60	50 exposed.

It will be seen that the maximum measurements for the several zones in the South are not so very much less than those estimated for the Yorkshire coast. The thickness of the 210 ft. allotted to the zone of *Terebratulina gracilis* was calculated at Crowe's Shoot, Speeton Cliff, where we can get a contact between this zone and that of *Holaster planus.* Though the total thickness of the flinty chalk will probably be determined at a future time with some approach to accuracy, it is not likely that the zonal measurements will ever be estimated with any degree of exactitude, for the simple reason that zonal junctions cannot be obtained in tide-bound or inaccessible cliffs. For further details concerning the estimated thickness of the zones of *Terebratulina gracilis, Holaster planus,* aud *Micraster cor-testudinarium* the reader is referred to pp. 208, 211, 213.

Leaving the purely zonal measurements, it may be useful to compare the total measured thickness of the White Chalk in Kent, Sussex, Dorset, and Devon with that now estimated for Yorkshire. In the case of Dorset and Devon we have taken the highest measurements obtained, so that the total represents the maximum thickness of the White Chalk measured by us in each locality.

		Ft. in.
KENT	... (Zone of *Rhynchonella cuvieri* to zone of *Marsupites testudinarius*)	717 6
SUSSEX	... (Zone of *Rhynchonella cuvieri* to zone of *Actinocamax quadratus*	917 0
DORSET	... (Zone of *Rhynchonella cuvieri* to zone of *Belemnitella mucronata*)	1,222 0
DEVON	... (Zone of *Rhynchonella cuvieri* to zone of *Micraster cor-testudinarium*)	346 0
YORKSHIRE.	(Zone of *Rhynchonella cuvieri* to zone of *Actinocamax quadratus* on coast 1,112 ft. 8 in. Estimated higher *quadratus*-chalk inland 150.	1,262 8

It will be noted that the coast measurements of Dorset alone surpass those of Yorkshire, but that if we add the minimum thickness of *quadratus*-chalk, higher than that on the coast, exposed S.W. of Bridlington, the positions are reversed. It must be remembered that in Dorset we have 250 ft. (exposed) of *mucronata*-chalk to swell the total. We have not yet estimated the thickness of the White Chalk in the Isle of Wight and Norfolk, and for this reason prefer not to bring them into the table of comparison.

CONCLUSION.

The record of the fauna in this area constitutes a veritable zoological romance. Verily it is a land of strange zonal occurrences, and of still more strange zonal omissions. It is, indeed, the remarkable absence of some of the commonest zonal fossils,

together with the unreliability of others which do exist, which has rendered the task of zoning this chalk so difficult, but, withal, so fascinating. We need go no further than the commonest echinids to substantiate our statements. With *Micraster* a mere museum curiosity on the coast, and with *Echinocorys* so badly preserved that we cannot follow its zonal shape-variations, we are indeed in a parlous state from the zone of *Holaster planus* upwards. Further, the vertical range of certain fossils, usually restricted in their distribution, is so vast that their very persistence is bewildering. As instances of this contention we may quote a range of 800 ft. for *Actinocamax granulatus*, and 650 ft. for *Actinocamax verus*; while *Cardiaster ananchytis* has been traced for 640 ft., and *Infulaster rostratus* for nearly 700 ft.

That *Actinocamax verus* should be found in the *quadratus*-chalk; that *Actinocamax granulatus* should be found some 350 ft. up in the same zone; that *Infulaster rostratus* should range from the zone of *Micraster cor-testudinarium* to that of *Actinocamax quadratus*; and that *Cardiaster ananchytis* should extend from the *Micraster cor-anguinum*-zone to the same horizon, are facts sufficiently unusual to warrant special comment.

We hardly looked to the barren chalk of Yorkshire to enlarge our knowledge of the distribution of these fossils, but this very extension of range is, in point of fact, one of the most conspicuous results of our work in this area. Moreover, we have here been able to fill in certain puzzling gaps in our chain of evidence concerning the distribution of other fossils. Reighton and North Sea Landing have given us two new zones, those of *Terebratulina gracilis* and *Holaster planus*, for the range of *Kingena lima*; and the Bessingby quarry, high up in the *quadratus*-chalk, has shown us that *Micraster*, usually absent in this zone in the south, is here found in a band yielding fair numbers of this urchin. We have shown that the same high horizon in Dorset also supplied us with some examples; so that we are gradually accumulating data whereby we may in time fill in the gap in the distribution of this echinid between the zone of *Marsupites testudinarius* and that of *Belemnitella mucronata* of Studland and Norwich. Still reverting to *Micraster*, we have pointed out that a section of the *Holaster planus*-zone at North Sea Landing exists which has never yielded an example of this genus, and that the local collections contribute but four unlocalised specimens (Mortimer Museum) from this horizon.

No inland exposure of this zone has as yet furnished a single specimen of *Micraster leskei* or *Micraster cor-bovis*.

We knew that we should meet with some fossils in Yorkshire which were strangers to our southern sections, but we were hardly prepared for the wealth of *Actinocamax* and *Inoceramus* which is here displayed. The zone of *Actinocamax quadratus*, which is not only the most fossiliferous, but the most widely

developed in this area, was the one to which we looked for best results. In this we were not disappointed, for the Flamborough calcite sponges, *Inoceramus lingua*, *Scaphites*, *Hamites*, and *Avicula tenuicostata*, were all new to our experience, and we believe to that of most other workers in the Southern Chalk.

Our only record, so far as we know, new to the English Chalk, is that of *Ostrea proboscidea* in the zones of *Terebratulina gracilis* and *Holaster planus* at Crowe's Shoot and North Sea Landing.

But the very barrenness of this coast, together with the notable absence of some of the common zonal guide-fossils, while it exhibits convincing evidence of the working of variation in geographical distribution, at the same time affords overwhelming proof of the validity and homogeneity of the zonal theory. The zones of *Rhynchonella cuvieri* and *Terebratulina gracilis* are quite in a line with southern sections, poor though their fauna undoubtedly is; and it is only when we reach the horizon where *Micraster* usually plays an important part that our difficulties arise. However, even here, in the zones of *Holaster planus*, *Micraster cor-testudinarium*, and *Micraster cor-anguinum*, though confessedly rare, *Micraster* runs absolutely true in all the essential features of the test which we associate with these several zones in the more prolific South. And it is the same with the zone of *Actinocamax quadratus*, for while the name-fossil is absent in the incomplete exposures of this bed, *Cardiaster pillula*, though notably rare, is found at this horizon, and at this one alone. The zone of *Marsupites*, though lacking in many of its characteristic guide-fossils, exhibits the customary division into *Marsupites*- and *Uintacrinus*-bands; and *Zeuglopleurus rowei*, found at this horizon in Thanet, here obtains a second record in this zone.

The belemnites are so unusual in their range and distribution that we have felt it necessary to emphasise their importance by devoting a special section of this paper to their discussion. The notable fact is brought out that, though we have at least 350 ft. of this zone here displayed, it has as yet failed to yield a single example of the true *Actinocamax quadratus*, exhibiting in its stead a remarkable and progressive evolution in *Actinocamax granulatus* which brings this species, step by step, within measurable distance of the features characteristic of the name-fossil of this zone.

A reference to the Zonal Summaries of the beds of *Micraster cor-anguinum* and *Actinocamax quadratus* will show that we have been compelled to establish what we have termed a local equivalent name-fossil to emphasise at the same time the dominance of the local form, and the absence or rarity of the generally accepted index-species. But, so that southern geologists may have no misconception as to our meaning, we have placed the two zonal titles side by side.

The rarity of *Cardiaster pillula* once again brings up the old question of an appropriate name-fossil for the *Actinocamax quadratus*-zone, in view of the rarity and varying level at this horizon occupied by the characteristic belemnite. This element of unreliability in *Actinocamax quadratus* has caused at least one writer to propose the substitution of *Cardiaster pillula* for the usual name-fossil of the zone. The fact that one is so rare, that the other has yet to be discovered at this horizon in Yorkshire, will give pause to those who desire to found new zonal titles before the whole of any given zone in England has been thoroughly systematised.

The close resemblance of the fauna of the Yorkshire *quadratus*-chalk with that of the same zone in North-West Germany has tempted us to summarise the Continental literature on the subject, so that the comparison might be made the more effective. But on looking into the matter we find that the literature is so extensive that it has been impossible to make a digest of it for the present paper.

Remarkable as are the zoological features of this section, the lithological characters are hardly less noteworthy. Seven hundred feet of chalk without a flint, and 555 feet crowded with immense tabular flint-bands, while two-thirds of the whole is traversed by innumerable seams of marl, make up a picture as strange as it is new to the rest of England. Possibly the presence of marl may indicate either a shallowing of the sea, or a proximity to land. If it be due to the former cause it is curious that gasteropods are so notably rare.

In any case, the presence of a zone of *Micraster cor-anguinum* partly in flinty and partly in flintless chalk, and of *Marsupites* and *Actinocamax quadratus*-zones wholly in the latter, must surely give the *coup-de-grâce* to those who still cling to the time-honoured tradition of a Chalk with flints and a Chalk without flints.

Among the curiosities of the coast are a zone of *Rhynchonella cuvieri* not exceeding 11 ft. in thickness, and an attenuated representative of the *plenus*-marls which does not yield its name-fossil.

It will be noticed that several of the plates have no key-plates attached to them, and the reason for such a course is that in these instances no zonal junctions are shewn, and the plates are simply designed to shew the configuration of the coast and the nature of the chalk at the points indicated.

It is a novelty to meet with any local geologists in the course of our work, and our stay in Yorkshire has been rendered by contrast all the more pleasant by reason of the kind and generous treatment which we have received at the hands of the members of the Hull Geological Society. They have acted as guides to

this difficult coast, freely lent fossils, and given all information in their power. To Mr. J. R. Mortimer, Mr. J. W. Stather, Dr. Walton, Mr. T. Sheppard, and Mr. W. H. Crofts we therefore tender our hearty thanks for their friendly offices.

Professor H. E. Armstrong has, as usual, supplied us with photographs to illustrate this paper, and it would be difficult to thank him sufficiently for the time and labour expended in obtaining such practical and artistic results. The plates would have been even better had the conditions of weather been more propitious. Owing to the abnormal amount of fog on this coast several journeys to Flamborough have been practically barren of results.

Mr. C. Davies Sherborn has, as heretofore, shared the field-work, and has not only been responsible for the admirable map and cliff-sections which illustrate the text, but has also made a large model of the district on a scale of 6 ins. to the mile and 1 in. to 100 ft. vertical, so as to more graphically demonstrate the position of the various zones on the coast, and in the country immediately behind it. We have presented this model to the Municipal Museum of Hull as a small token of our gratitude to the members of the Geological Society of that city. The cliff-sections have entailed much thought, and the model has necessitated months of labour. Work such as this cannot be repaid by mere words.

To Mr. G. W. Lamplugh also we would express our lively sense of gratitude, for not only has he given us freely of his vast and unique store of local knowledge, but he has put all his notes and fossils at our disposal. We had the great advantage of his presence in the field during our second visit, when we submitted all our cliff-sections and measurements to his judgment. It would be impossible, indeed, to exaggerate our indebtedness to him.

Mr. G. W. Crick has not only described the interesting and unique deformity of *Actinocamax granulatus* in the Appendix to this paper, but has himself drawn the admirable figures which illustrate it. We have also to thank him for examining and determining several of our cephalopods.

From Dr. Johannes Böhm, Mr. J. J. H. Teall, Dr. G. J. Hinde, Dr. Henry Woodward, Professor J. F. Blake, Mr. E. T. Newton, Dr. A. Smith Woodward, Dr. J. S. Flett, Dr. F. L. Kitchin, Mr. J. A. Howe, Mr. H. A. Allen, Mr. Henry Woods, Dr. H. P. Blackmore, Mr. C. Griffiths, Mr. R. M. Brydone, Mr. G. E. Dibley, and Dr. A. Warwick Brown we have received invaluable aid, and to them we desire to express our cordial thanks for help so willingly given ; nor must we forget the ever ready kindness and consideration of Mr. J. Allen Howe, who has, in addition, seen the paper through the press.

So long as this paper is considered but as a preliminary

attempt to bring the fauna of the Yorkshire coast into line with that of our southern sections we are content. It makes no pretence to be an exhaustive monograph on the zones of this coast, still less on those of the sections in the inland area. Later on we hope to continue our researches, and to make the record not only more complete, but more worthy of a coast abounding in beauty, novelty, and profound and fascinating interest.

APPENDIX A.

NOTE ON A REMARKABLE BELEMNOID FROM THE CHALK OF FLAMBOROUGH HEAD.

By G. C. Crick, F.G.S., of the British Museum (Natural History).

From the zone of *Micraster cor-anguinum* at Flamborough Head, Dr. Rowe has obtained a Belemnoid which is worthy of special note. He tells me that he has never seen its like, even in Yorkshire, and that none of the local collections have anything resembling it. According to Dr. Rowe *Actinocamax granulatus* (H. D. de Blainville)* is the ordinary Belemnite in the *cor-anguinum* zone in Yorkshire, and it is common.

The present specimen has the structure of, and is clearly comparable with, the guard of an ordinary Chalk Belemnite. It is short and stout, and instead of being straight is slightly curved towards the antisiphonal surface.

Fortunately the specimen is almost perfect; it is represented of the natural size in the accompanying figures (A—D, Fig. 13).

The fossil is almost symmetrical. It is 19 mm. long, somewhat compressed, slightly inflated at about its mid-length, the transverse diameter being here about one-half of the length; posteriorly it tapers evenly to an obtuse laterally-compressed apex, which is turned towards the antisiphonal surface. Its cross-section is oval, the siphonal surface being broadly convex, the antisiphonal narrowly rounded. There is a broad, shallow, but well-marked depression (*d* in Figs. B and C) on each side near the antisiphonal area, the depression on one side being a little deeper, narrower, and more distinct than that on the other; at the anterior end of the specimen these depressions are 4·5 mm. apart; in passing backwards they gradually approximate, being at the apex only about 1 mm. apart. The anterior end is oval in outline, the dorso-ventral and transverse diameters being 10·5 and 9 mm. respectively, the greatest width being a little nearer the siphonal than the antisiphonal surface; it is hollow, conical, and partakes of the

* Mém. sur les Bélemnites, 1827, p. 63, pl. I, Fig. 10.

general curvature of the rostrum; its greatest depth below the highest part of the margin of the cavity is about 5 mm., the sides are not smooth but irregular, as is generally the case in *Actinocamax granulatus*. There was probably a siphonal slit (*s* in Figs. A and B) but this is scarcely shewn, the edge of the specimen being broadly V-shaped at the middle of the siphonal surface.

The anterior part of the siphonal surface bears feeble, transverse, somewhat irregular rugosities (Fig. A); there is also on one side, a little nearer the siphonal than the antisiphonal surface, a well-marked and incised furrow (*f* in Fig. C); starting at about 5 mm. from the anterior margin this line extends backwards and towards the siphonal surface for a distance of 3·5 mm., and then follows the general curvature of the rostrum for about another

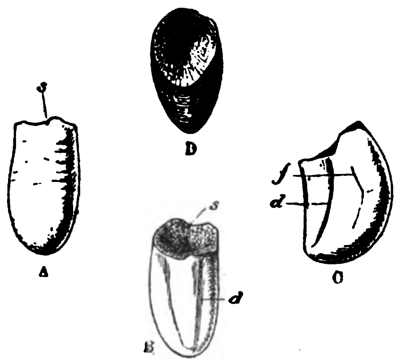
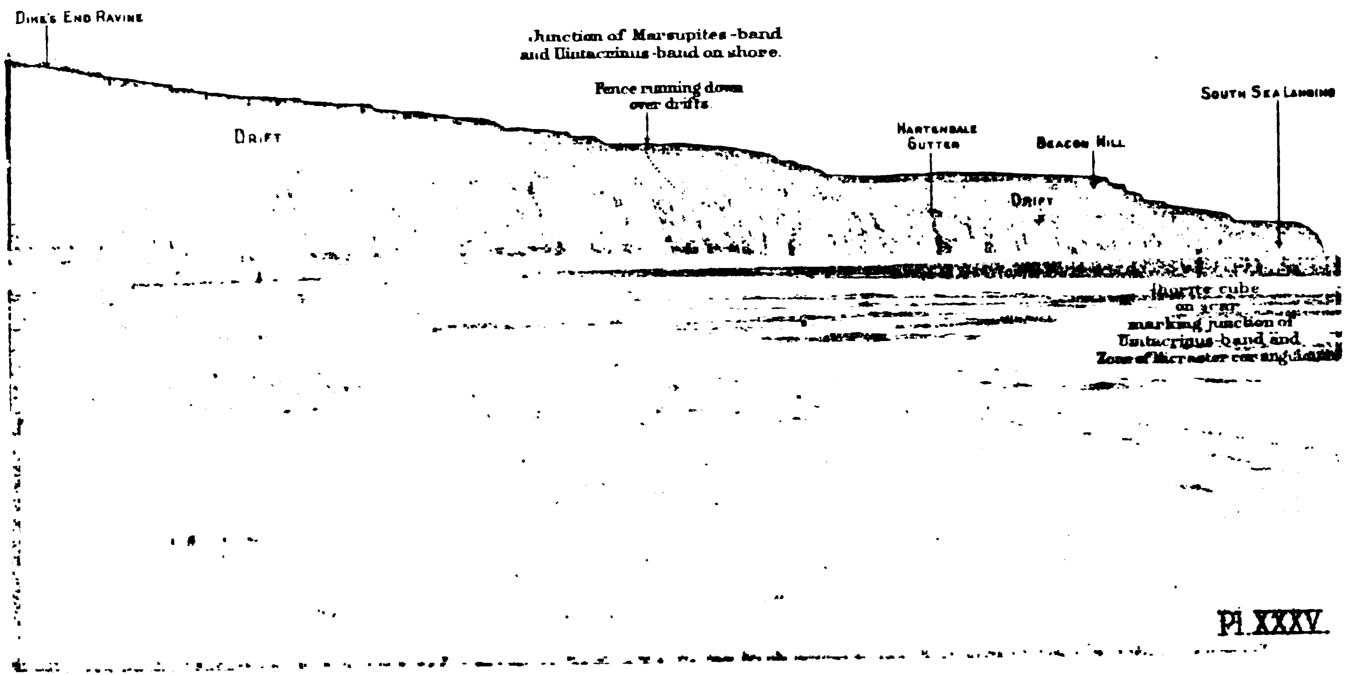


FIG. 13.—Deformed specimen of *Actinocamax granulatus*, H. D. de Blainville, sp.; from the Upper Chalk, zone of *Micraster cor-anguinum*, Flamborough, Yorkshire.—A, siphonal aspect; B, antisiphonal aspect; C, lateral aspect; D, antero-siphonal aspect. *d*, depression on each side of antisiphonal area; *f*, furrow on lateral area; *s*, posterior termination of siphonal slit. Drawn of the natural size.

6 mm. gradually becoming irregular and very faint. We cannot detect any trace of a similar incised line on the opposite side.

The affinities of the fossil are quite clear, but whether it should be regarded as an abnormal form of a known species, or a new species, or even a new genus, is not quite so evident.

The specimen is clearly related to *A. granulatus* (Blainville), a form which according to Dr. Rowe is common in the zone of *Micraster cor-anguinum* at Flamborough Head. At first sight the specimen appears to be almost perfectly symmetrical, but a closer examination shows that the apex is directed a little towards one side (Fig. B), and that one side of the fossil is a little more inflated than the other; also that the broad depression near the antisiphonal area is deep and quite distinct on one side (*d* in


DIKE'S END RAVINE
DRIFT
Junction of Marsupites-band and Uintacrinus-band on shore.
Fence running down over drifts.
HARTENDALE GUTTER
BEACON HILL
DRIFT
SOUTH SEA LANDING
cube
marking junction of
Uintacrinus-band and

Pl. XXXV.

general curvature of the rostrum; its greatest depth below highest part of the margin of the cavity is about 5 mm., the are not smooth, but irregular, as is generally the case in *Actinocamax granulatus*. There was probably a siphonal slit (*s* in A and B) but this is scarcely shewn, the edge of the spe being broadly V-shaped at the middle of the siphonal surf

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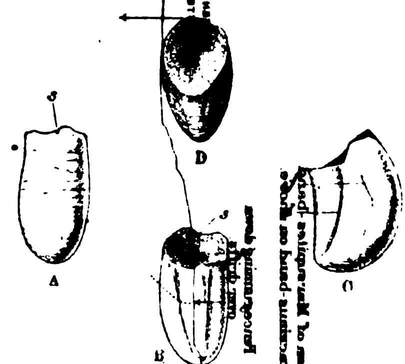

FIG. 13.—Deformed specimen of *Actinocamax granulatus*, H. D. ... sp.; from the Upper Chalk, zone of *Micraster cor-anguinum*, F... Yorkshire.—A, siphonal aspect; B, antisiphonal aspect; C, lateral ... D, antero-siphonal aspect. *d*, depression on each side of antisiph... *f*, furrow on lateral area; *s*, posterior termination of siphonal slit. ... the natural size.

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DIKE'S END TO SOUTH SEA LANDING. ZONES OF MARSUPITES AND MICRASTER COR-ANGUINUM.

Figs. B and C), whilst on the opposite side it is represented merely by a relatively broad flattened area; further the fine furrow (*f* in Fig. C) which exists on the lateral area and near the siphonal side, and which is usually very distinct in *A. granulatus*, is fairly distinct on the side bearing the deeper lateral depression, whilst on the opposite side no such line can be detected.

The form of the anterior end is precisely that of *A. granulatus*.

Although the guard does not exhibit any definite injury such as is usually seen in deformed specimens, there appears to be every reason to believe that the fossil is simply an abnormal form of *Actinocamax granulatus*.* The hollow anterior end partakes of the general curvature of the specimen, so that whatever produced the abnormality of the fossil affected it from quite an early stage in its existence.

APPENDIX B.

NOTES ON THE CLIFF-SECTIONS, MAP, AND SECTIONS.

By C. Davies Sherborn, F.G.S., F.Z.S.

Cliff-sections.—The reader must remember that Flamborough Head has the form of a triangle, whose base is represented by a line drawn from Speeton to Bridlington, and whose apex points to the North Sea. These cliff-sections represent the two sides of this triangle; from Bridlington to the Head, and from Speeton to the Head; the beds are dipping from Speeton to Bridlington roughly S.S.E., the rising edge of the saucer being seen at Speeton, as will be recognised by a glance at the map.

The section begins at Sewerby, at the drift-buried chalk cliff (for description of which interesting feature see Lamplugh and others, *Reports British Association* for 1888, 1889, 1890) where the *quadratus*-beds are nearly horizontal, owing to the close coincidence of the cliff-line with the strike. About 650 feet before we reach Dane's Dike path, at four black rocks on the shore, is seen the junction between the *quadratus*-chalk and the *Marsupites*-band, and at this point the beds begin to rise. Although obscured by the cut-out of the Dane's Dike valley, we do not consider that there is any sign of a fault. About 300 feet E. of the Dike, and on the top of the cliff, is seen a fence; this approximately marks the junction between the *Marsupites* and *Uintacrinus* bands, and a few feet further on *Uintacrinus* comes in in abundance. A large, dark block of diorite on the shore marks

* For a somewhat similarly deformed example of *Belemnitella mucronata* see C. Schlüter, Palaeontographica, Bd. xxiv, Pl. lv, Fig 8.

the junction with the *Micraster cor-anguinum* zone, but *Uintacrinus* may be collected almost at the foot of the cliff 150 yards further towards South Sea Landing, because of the gentle rise of the beds in that direction. After passing South Sea Landing the eastward prolongation of the land makes the beds appear horizontal, and so the *Micraster cor-anguinum*-chalk continues to High Stacks. Climbing the path at High Stacks and descending again to the shore at Selwicks, we find the *Micraster cor-anguinum*-zone again fairly level. At the base of the chalk-stack on the west of Selwicks Bay we see the first line of flint in the *Micraster cor-anguinum*-zone, and taking advantage of the tide, go through the caves, and reaching Kindle Scar, where the cliff trends westwards, again notice the dip apparently rising to the west. From the top of Breil Head we can see the line of holes which apparently marks the junction between the *Micraster cor-anguinum* and the *Micraster cor-testudinarium*-zones, which latter joins the *Holaster planus*-zone about two-thirds up Newcombe. After passing Little Thornwick the beds again appear horizontal on the cliff-face until we reach Kit Pape's Spot. The disturbance at Old Door, great as it appears, does not in our opinion, materially affect the beds; we think it merely a local nip, and are confirmed in our opinion because a section drawn from Speeton to Speeton Station gives quite a normal and regular sequence of the zones. It has not been thought worth while to shew the cliff beyond Kit Pape's Spot as the beds rise rapidly and are fully described in the text.

We have not attempted to survey the Drifts in any way and have therefore merely indicated them upon the sections. Those interested will find a complete and detailed account in, *Lamplugh*, *Q. J. Geol. Soc.*, xlvii, 1891.

MAP.—The map, which is reproduced from the one inch to the mile Ordnance Survey map, represents the actual result of an examination of 32 pits, 28 of which were zoned without the slightest trouble by means of their fossil contents. More information is of course desirable.

SECTIONS.—The sections, of which we give two, are diagrammatic, and based on the cliff-sections and pits. The first, Kit Pape's Spot to Buckton Hall, is calculated at ten degrees for the first half-mile (see pit No. 3), and five degrees (the average dip) for the second half-mile. It shows the small effect of the Old Door disturbance even at this distance away, and judging by the data afforded us from a study of the pits, the disturbance dies out before we reach the Speeton to Speeton Station section. The second section shows diagrammatically the condition of things between Gull Nook and Flamborough Station. We are pleased to say that Mr. Lamplugh, who has gone carefully into the matter with us, approves of these diagrams as approximately representing the facts observed.

APPENDIX C.

NOTE ON THE CONDITIONS OF ACCUMULATION OF THE YORKSHIRE CHALK AS SHOWN BY THE STATE OF PRESERVATION OF THE FOSSILS.

BY G. W. LAMPLUGH

Having had the privilege of accompanying Dr. Rowe in the field for a few days during his investigation of the Yorkshire Chalk, and having further been favoured by his permission to read the advance-proof of the foregoing paper, I feel it almost a duty to accede to his request to add a note on any point connected with the physical characters of the formation which may be supplementary to the brilliant results achieved by him in this field.

During my youth I collected largely, but in a somewhat aimless and desultory fashion, from the "Sponge Beds" between Sewerby and Dane's Dyke, and became gradually interested as much in the mode of preservation of the fossils as in their specific characters. My intention some time to investigate this aspect of the fossils more thoroughly has lingered, but has never approached fulfilment. The present opportunity tempts me to try, at any rate, to indicate the lines along which the investigation would have been carried if circumstances had favoured its continuance; but as I am writing mainly from memory and without access to my collection, this note must be taken merely as suggestive of work worth doing.

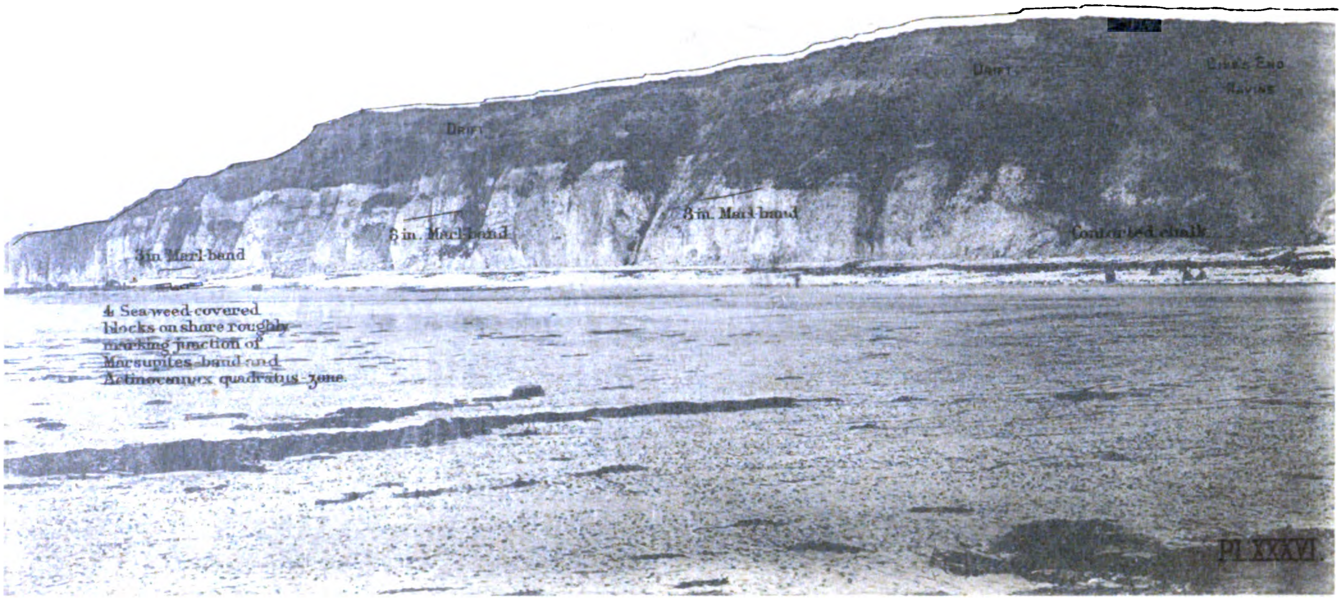
The lithistid sponges which are so abundant at a definite horizon in the Chalk around Bridlington are of very diverse shapes and sizes, including a large number of cylindrical forms—which may be roughly compared to cucumbers and melons in outline but with thicker stems—and others taking the form of expanded and often convoluted discs, in shape resembling mushrooms and other fungi. The cylindrical forms, which occasionally attain a length of 18 inches or more, and a diameter ranging up to 4 or 5 inches, have grown upright, or nearly so, on the sea-floor, anchored in the calcareous mud by a digitating root-like base at the end of a long stem. But I have never seen a well-grown specimen of the cylindrical sponge in the attitude of life—all except the very small examples are lying prone in the Chalk and have usually been broken off at the narrow part of the stem, a little above the "roots." When of small diameter, say, not exceeding 2 inches, the cylinder is generally well-preserved, with the surface-moulding intact; but the more inflated specimens are usually well-preserved on the

under side only, while the upper side has undergone corrosion which has destroyed the surface and sometimes has reduced the cylinder to half its original diameter. From the rough irregular outline of the damaged surface and from its position in regard to the uninjured part of the fossil, it is probable that the corrosive agent was some lowly organism of which no other trace now remains; the results are certainly not those of merely mechanical abrasion, and I do not think that they could be explained by chemical action. In conversing recently with Mr. J. E. Duerden, who has done much work on the marine zoology of the West Indies, I was much impressed by what he told me of the manner in which, in that region, the framework of dead corals was reduced to calcareous mud by destructive organisms, apparently under conditions somewhat analogous to those of the Chalk seas.

If we could obtain some measure of the rate at which their corrosion progressed, these damaged sponges might enable us to frame an estimate of the rate of accumulation of the Chalk. Evidently the action did not go on below the surface of the soft calcareous mud into which the specimens fell, and it would therefore be arrested as soon as they were completely buried.

There are other questions of great interest raised by this condition of the fossils. If the massive sponges have been corroded to this extent, how far has the destructive agency gone in completely obliterating other relics of animal life which lay exposed upon the sea-bottom; and to what extent is the Chalk matrix itself due to this pulverising action?

To the first of these questions we may, I think, answer without hesitation, that the fossils preserved in the Yorkshire Chalk very imperfectly represent the life of the ancient sea, even in respect of the hard-shelled mollusca, without taking into account the soft-bodied animals which are so rarely preserved under any conditions. There is a very striking piece of evidence, hitherto, I believe, unrecorded, which bears directly upon this point. Mr. J. R. Mortimer possesses in his collection at Driffield several very large Ammonites from the Chalk (to which the MS. name of *Amm. Wharramiensis* is affixed), and in removing one of these monsters, over 3 feet in diameter, from its bed in a quarry at High Towthorpe, he noticed beneath it an agglomeration of small fossils, and took pains to preserve numerous specimens from this "nest." The material, besides being rich in the teeth of fish, plates of cidaris, small corals, serpulæ, and sponges to an altogether exceptional degree, contains the casts of some small, richly-decorated, cerithiform and trochiform gasteropods, not yet specifically determined, which have never, to my knowledge, been found elsewhere in the Yorkshire Chalk. The huge shell after the death of its inmate must have sunk into the mud and shielded beneath it this little sample of the old sea-



Dike's End and Sewerby Cliff. Marsupites-band and zone of Actinocamax quadratus.

under side only, while the upper side has underg[illegible] which has destroyed the surface and sometimes [illegible] the cylinder to half its original diameter. [illegible] irregular outline of the damaged surface and [illegible] [illegible]ed to the uninjured part of the fossil, it is [illegible] the corrosive agent was some lowly organism of [illegible] no [illegible] now remains; the results are certainly not [illegible] of mechanical abrasion, and I do not think that [illegible] explained by chemical action. In conversing [illegible] J. E. Duerden, who has done much work on [illegible] of the West Indies, I was much impressed by [illegible] he t[illegible] of the manner in which, in that region, the framework of corals was reduced to calcareous mud by destr[illegible]ve [illegible] apparently under conditions somewhat analogous [illegible] Chalk seas.

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Dike's End and Sewerby Cliff. Marsupites-band and zone of Actinocamax quadratus.

floor from the disintegrating agencies which would otherwise have destroyed most of the organic remains before the slowly-accumulating sediment could cover and protect them.

Of shells composed of aragonite, the only traces left in our northern Chalk are the obscure casts of a few cephalopods and of a gigantic Pleurotomaria, except in the above-cited instance. It is only the more enduring calcite shells which have, in limited numbers, escaped destruction. This is a factor which must always be taken into our calculations in dealing with the life-history of this region of the Chalk seas.

As to the extent to which the pulping-down of calcareous bodies by lowly organic agencies may have contributed to the accumulation of the chalk, that is a matter on which no opinion is worth expressing unless supported by microscopical and biological investigation, but my impression is that it has been considerable.

The occurrence of structures in the rock which are probably due to shrinkage during consolidation has been referred to in Dr. Rowe's "Lithological Summary." Very pretty examples of structures of this kind may sometimes be noticed in excavating the fungiform sponges, the discs of which occasionally form the capping of a short cylindrical column of chalk, through the development of a slight shear-plane between the rock under the shelter of the hard disc and the surrounding unprotected matrix. Structures of this kind deserve closer attention than they have yet received.

Dublin, Nov., 1903.

NOTES ON THE PLATES.

PLATE XVII.—View taken west of Kit Pape's Spot, where the "black band" falls to the shore, at the eastern end of the Buckton Cliffs. The position of the vertical fault, the overthrust fault, and the "black band" is indicated. On the east side of the vertical fault an incomplete exposure of the flintless zone of *Rhynchonella cuvieri* is seen, and this is overlain by the flinty chalk of *Terebratulina gracilis*. The succession is here normal. On the west side of the vertical fault is seen the "black band" which lies in the horizontal fissure caused by the overthrust fault. Below the "black band" the *Holaster subglobosus*-zone is seen, and above it the flinty *gracilis*-chalk. The flintless bed of *Rhynchonella cuvieri* is crushed out by the overthrust fault, and thus explains the appearance of apparent unconformity.

PLATE XVIII.—Taken a little farther west than Pl. XVII, and showing the same physical features, but on a larger scale. The flint courses in the white *gracilis*-chalk are plainly seen, and Mr. Sherborn's hammer is resting on the lowest one. This is the section described by Mr. Dakyns. The "black band" cannot be seen in the photograph, as it lies in the shadow of the horizontal fissure.

PLATE XIX.—Taken fifty yards farther west than Pl. XVIII, and showing the normal succession of zones from *Holaster subglobosus* to *Terebratulina gracilis*. The cliff is crowned by the zone of *Holaster planus*. The "black band" is here split into three lines. The measuring rod is pointing to the lowest yellow marly band in the flintless chalk of *Rhynchonella cuvieri*.

PLATE XX.—The conditions west of Kit Pape's Spot are so peculiar that it has been thought desirable to show the best inland exposure which embraces the same zonal series, namely, South Ferriby quarry, near Barton-on-Humber, Lincolnshire. Here we have the normal succession from the zone of *Holaster subglobosus* to that of *Terebratulina gracilis*. The position of the "black band" is clearly shewn, and the contrast between the flintless *Rhynchonella cuvieri*-zone and the flinty gracilis-beds is well brought out. The "black band" is a portion of the *plenus*-marls, and it yields the characteristic belemnite. The "black band" in Yorkshire is its local stratigraphical equivalent, but the belemnite has never been found in it.

PLATE XXI.—To indicate position of Jackdaw's Crag and Nanny Goat's House. The cliffs in the foreground are cut in *gracilis*-chalk alone, while those to the left of the picture are capped with the zone of *Holaster planus*. The point in the distance is not Kit Pape's Spot.

PLATE XXII.—At Speeton Cliffs in zone of *Terebratulina gracilis*. Lower beds hidden by screes.

PLATE XXIII.—The same. The three plates give the whole range of the Speeton Cliffs from east to west.

{ PLATE XXIV.—Scale Nab and the famous Contortions.
{ PLATE XXIV.—Detail of the Contortions. Through the courtesy of the Council of the Yorkshire Geological and Polytechnic Society we are able to give these reduced reproductions from their series of large plates.

PLATE XXV.—West side of Great Thornwick. The relative position of Little Thornwick, Chatterthrow, and Sanwick can be made out. The Bempton Cliffs are cut in the zone of *Terebratulina gracilis*, and are capped by that of *Holaster planus*. The four bays are in the lower zone alone. The thickness of the drifts on the low cliffs is well shewn, and contrasts with the thin capping on the high Bempton Cliffs.

PLATE XXVI.—Sanwick Bay, west of Thornwick, the latter being seen in the distance. This is one of the best examples of erosion on the coast. Zone of *Terebratulina gracilis*.

PLATE XXVII.—Chatterthrow, Little Thornwick, and Great Thornwick. A well-known example of aerial sculpturing of drifts, and marine erosion of rock. Zone of *Terebratulina gracilis*.

PLATE XXVIII.—North Sea Landing from the south. Zone of *Holaster planus*.

PLATE XXIX.—Breil Head, and Cradle Head in the distance. The line of holes which roughly defines the junction of the zones of *Micraster cor-testudinarium* and *Micraster cor-anguinum* is well brought out in the photograph. The base of the cliff is cut in the former zone.

PLATE XXX.—North Sea Landing: Paramoudra 3 ft. across. The main mass lies under the measuring rod, and the narrow end is separated from it. The mass immediately above the measuring rod is a tabular band of flint a foot in thickness, and the two masses above that are chalk. These Paramoudras are a feature of this zone (*Holaster planus*), and their position is discussed on p. 209.

PLATE XXXI.—Selwicks Bay from the north. The whole of these cliffs are in the zone of *Micraster cor-anguinum*.

PLATE XXXII.—The head of Selwicks Bay, shewing the position of the fault described by Mr. Lamplugh. It will be noted that the left-hand cliff is in horizontal flinty chalk; that a wedge-shaped mass of the middle bluff is of the same nature, while the bulk of it is crushed and contorted; and that the right-hand cliff is in horizontal flintless chalk. The position of the fault is hidden by a talus of drift. For description of this fault by Mr. Lamplugh, see his own paper, which is quoted on p. 215 of this work. The whole of this bay is in the zone of *Micraster cor-anguinum*.

PLATE XXXIII.—The King and Queen Rocks at Breil Point. This beautiful picture is included in the series to shew the way in which this rugged coast is fretted away by the sea. They are probably based in the zone of *Holaster planus* and capped by that of *Micraster cor-testudinarium*

PLATE XXXIV.—The High Stacks, Flamborough Head. On the far side of this little headland we see the last line of flints, where the flinty and flintless beds of the *Micraster cor-anguinum*-zone blend. For description of this see p. 215. The crater-like hollow in the picture is caused by the falling-in of the drift roof of a cave. While the opening was yet small the sea on rough days rushed into the narrow cave and the spray was forced out of the opening in the roof in a vertical column.

PLATE XXXV.—Dike's End to South Sea Landing, shewing junction of *Marsupites*-band and *Uintacrinus*-band, and of the latter with the zone of *Micraster cor-anguinum*. The junction of the two former is marked by the fence running down over the drifts, and of the two latter by the 3-ft. cube of diorite on the white scars under Beacon Hill.

PLATE XXXVI.—Dike's End and Sewerby Cliff, showing junction of *Marsupites*-band and zone of *Actinocamax quadratus* at the four seaweed-covered blocks on the shore 15 ft. 6 in. below the 3-in. marl-band. The remainder of the cliff, from this point to Bridlington, is all in the zone of *Actinocamax quadratus*.

PLATE XXXVII.—Suture-partings in *gracilis*-chalk, Great Thornwick. For reference to this condition see p. 228.

PLATE XXXVIII.—Section of the Cliff-face from Bridlington to Speeton.

PLATE XXXIX.—Diagrammatic section from Kit Pape's Spot to Buckton Hall, and from Gull Nook to Flamborough Station.

PLATE XL.—Map of Flamborough Head, shewing the zones of the White Chalk.

Colour scheme :—

Sienna = Beds below the White Chalk.
Green = *Terebratulina gracilis*-zone.
Indigo = *Holaster planus*-zone.
Yellow = *Micraster cor-testudinarium*-zone.
Red = *Micraster cor-anguinum*-zone.
Light Blue = *Marsupites*-zone.
White = *Actinocamax quadratus*-zone.

The numbers in circles refer to chalk pits.

NOTES ON THE PLATES AND KEY-PLATES.

Abbreviations used.

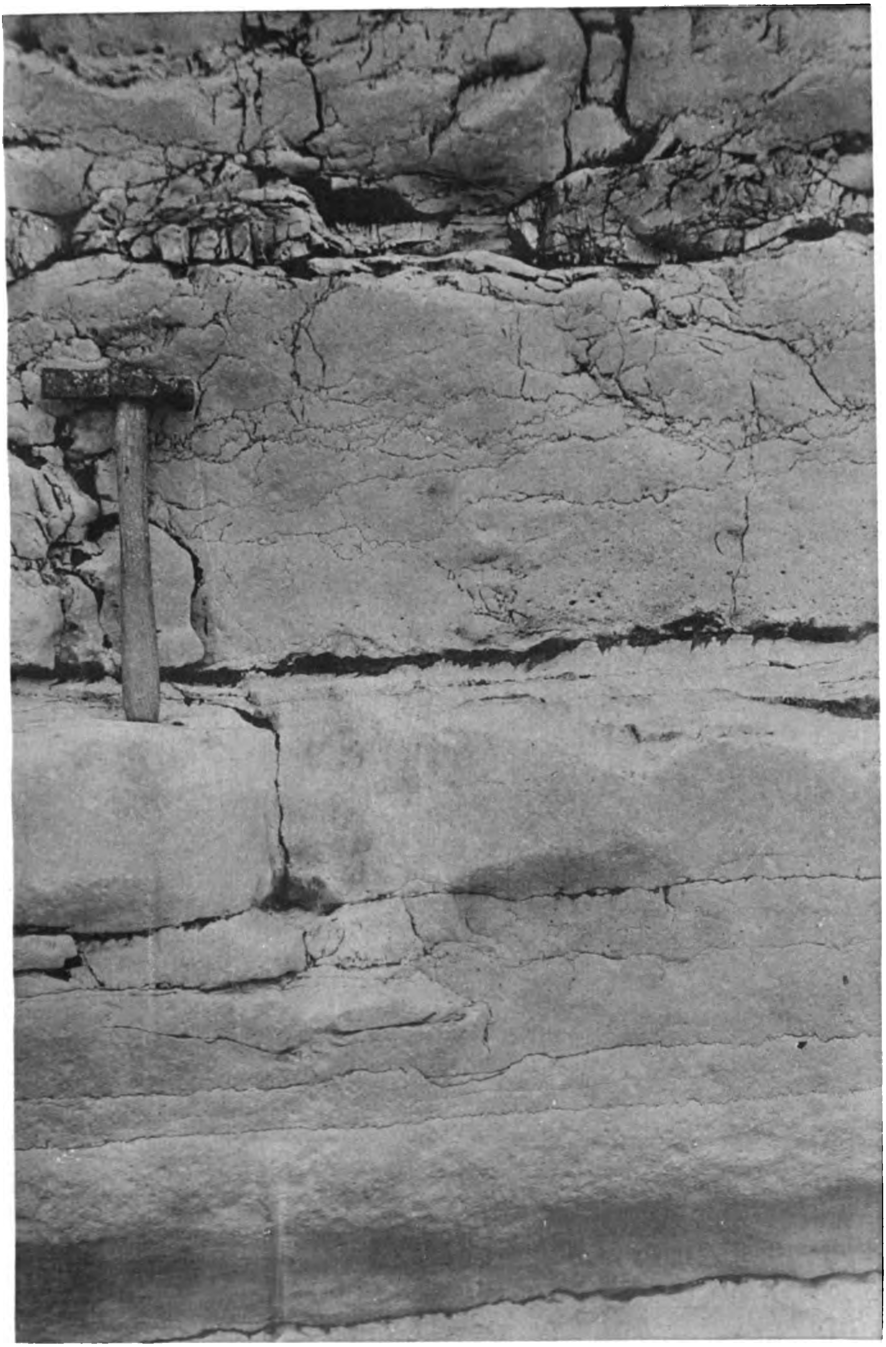
R. c.	=	Zone of *Rhynchonella cuvieri*.
T. g.	=	„ „ *Terebratulina gracilis*.
H. p.	=	„ „ *Holaster planus*.
C. t.	=	„ , *Micraster cor-testudinarium*.
C. a.	=	„ „ „ *cor-anguinum*.
U.	=	*Uintacrinus*-band.
M.	=	*Marsupites*-band.
A. q.	=	Zone of *Actinocamax quadratus*.

In all cases the extent of the main zonal exposures is indicated by a strong vertical line, and the zonal junction by a short line at right-angles to it. If a zone is incompletely exposed, either in an upward or downward direction, the short horizontal line is omitted. The names of the chief zonal exposures are indicated in thick type.

LIST OF FOSSILS FROM THE YORKSHIRE COAST.

C. common; R.C. rather common; R. rare; R.R. rather rare.

	Zone of *Rhynchonella cuvieri.*	Zone of *Terebratulina gracilis.*	Zone of *Holaster planus.*	Zone of *Micraster cor-testudinarium.*	Zone of *Micraster cor-anguinum.*	Zone of *Marsupites.*	Zone of *Act. quadratus.*
Ventriculites radiatus, Mant.	...	...	...	...	C.	C.	C.
Ventriculites cribrosus, Phill.	...	...	...	R.	R R.	R.	R.C.
Ventriculites impressus, T. Smith	...	...	...	...	...	R.	R.R.
Ventriculites infundibuliformis, S. Woodw.	...	...	...	...	...	...	C.
Ventriculites convolutus, Hinde	...	...	...	...	...	R.	R.
Ventriculites decurrens, T. Smith	...	..	...	...	R.	R.C.	R.C.
Plocoscyphia convoluta, T. Smith	...	...	...	R.	C.	C.	C
Porochonia simplex, T. Smith	...	...	...	...	...	R.	C
Coscinipora infundibuliformis, Goldf.	...	...	...	...	R.R.	C	C
Guettardia stellata, Mich.	...	...	...	...	R.R.	R.R.	R.C.
Leptophragma murchisoni, Goldf.	...	...	...	...	R.	R.C.	R C.
Cœloptychium agaricoides, Goldf.	...	...	...	...	...	...	R.C.
Callopegma obconicum, Hinde	...	...	...	...	...	...	R.
Heterostinia obliqua, Benett	...	...	...	...	R	C.	C.
Siphonia Königi, Mant.	...	...	...	...	R.	R.C	C.



SUTURE-PARTINGS IN GRACILIS CHALK, GREAT THORNWICK.

(?) *Stelletta inclusa*, Hinde	...	...	...	...	...	R.	C.
Cliona cretacea, Portl.	...	...	...	R.C.	C.	C.	C.
Porosphæra globularis, Phill.	...	R.	R.	R.	C.	C.	C.
Porosphæra globularis var. *nuciformis*, Hinde	...	...	...	...	R.	R.	R.R.
Porosphæra pileolus, Lam.*	...	...	R.	R.	R.R.	R.	R.
Porosphæra pileolus var. *patelliformis*, Hinde	...	...	...	...	R.R.	...	R.
Porosphæra pileolus var. *arrecta*, Hinde	...	...	...	...	R.	...	...
Spinopora dixoni, Lonsd.	...	...	...	...	R.	...	...
Cælosmilia laxa, E. and H.	...	...	...	...	...	...	R.
Parasmilia centralis, Mant.	...	...	R.	...	R.C.	R.R.	...
Parasmilia fittoni, E. and H.	...	...	...	...	...	R.	...
Parasmilia cylindrica, E. and H.	...	...	...	...	...	R.	...
Parasmilia granulata, Dunc.	...	...	...	...	R.	...	...
Axogaster cretacea, Lonsd.	...	...	...	...	...	...	R.
Asteroidea	...	R.	C.	R.	C.	R.C.	C.
Bourgueticrinus	...	R.	R.C.	R.	R.C.	R.R.	R.R.
Pentacrinus	...	...	R.R.	...	...	...	...
Marsupites testudinarius, Mill.	...	...	...	...	...	C.	...
Uintacrinus	...	...	...	...	...	C.	...
Ophiura	...	...	...	...	...	R.	...
Cidaris sceptrifera, Mant.	...	...	...	...	R.C.	R.C	R.
Cidaris clavigera, König	...	...	...	...	R.	...	...
Cidaris hirudo, Sorig.	...	R.	R.	...	...	R.C.	C.
Cidaris subvesiculosa, d'Orb.	...	...	...	R.	R.R.	R.C.	R.
Cyphosoma radiatum, Sorig.	...	R.	...	...	...	...	...
Cyphosoma corollare, Klein	...	...	...	...	R.	...	R.
Salenia granulosa, Forbes	...	R.	...	...	...	R.	...
Zeuglopleurus rowei, Greg.	...	...	...	...	...	R.	...
Echinocorys vulgaris, Breyn	...	...	R.C.	R.	R.C.	R.C.	R.C.
Micraster cor-anguinum, Leske	...	...	...	...	R.	...	R.

* For a record of the calcite sponges of Flamborough Head, see G. J. Hinde, Cat. Brit. Mus., Fossil Sponges, and p. 263 of this paper.

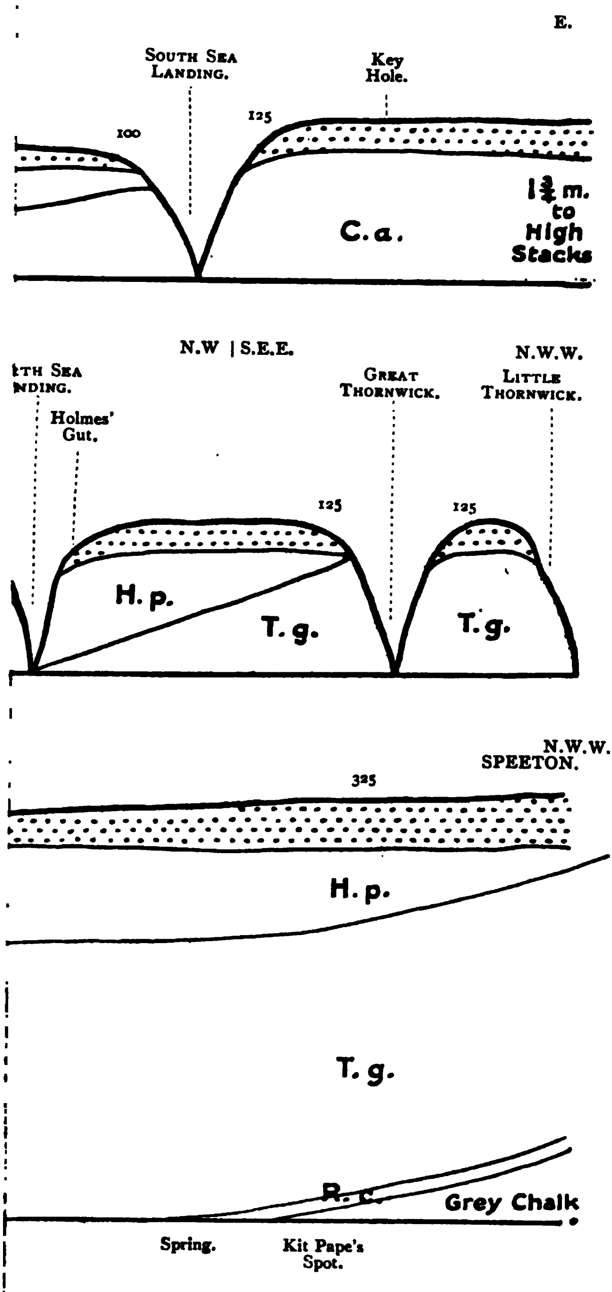
LIST OF FOSSILS FROM THE YORKSHIRE COAST.—*Continued.*

	Zone of *Rhynchonella cuvieri.*	Zone of *Terebratulina gracilis.*	Zone of *Holaster planus.*	Zone of *Micraster cor-testudinarium.*	Zone of *Micraster cor-anguinum.*	Zone of *Marsupites.*	Zone of *Act. quadratus.*
Micraster præcursor, Rowe (group)	...	...	R.	R.	...	...	...
Infulaster rostratus, Forbes	...	...	...	R.	C.	R.	R.R.
Hemiaster minimus, Ag.	...	R.	...	...	...	...	...
Holaster planus, Mant.	...	C.	C.	...	...	...	...
Holaster placenta, Ag.	...	...	R.	R.	...	...	...
Cardiaster cotteaui, d'Orb.	...	...	...	R.R.	...	...	...
Cardiaster pillula, Lam.	...	...	...	...	...	...	R.
Cardiaster ananchytis, Leske	...	...	...	...	R.	R	C.
Serpula ampullacea, Sby.	...	...	...	...	R.	...	R.
Serpula fluctuata, Sby.	...	...	...	...	...	R.	...
Serpula granulata, Sby.	...	...	...	...	R.	R.	...
Serpula ilium, Sby.	...	...	...	...	...	R	...
Serpula turbinella, Sby.	...	...	...	R.	R.C.	...	R.
Serpula plana, S. Woodw.	...	...	...	...	R.	...	...
Crania egnabergensis, Retz.	...	R.	R.	R.	R.R.	R.	R.R.
Thecidea sp.	...	...	...	...	...	R.	...
Kingena lima, Defr.	...	R.	R.	...	R.	R.	R.R.
Terebratulina striata, Dav.	...	R.	R.	...	R.R.	R.	R.R.
Terebratulina gracilis, Schl.	...	C	...	...	...	...	...
Terebratula semiglobosa, Sby.	R.R.	R.C.	R.C.	R.	R.C.	R.	R.R.
Terebratula carnea, Sby.	...	R.	R.R.	...	R.	...	...
Rhynchonella plicatilis, Sby.	...	...	R.	...	...	...	...

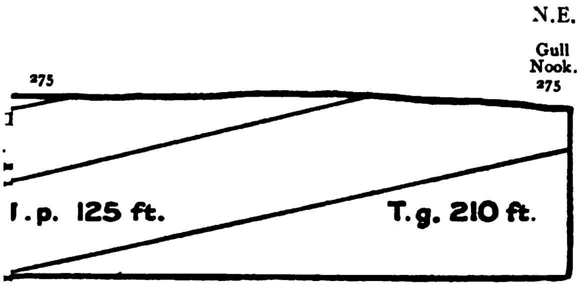
Rhynchonella limbata, Schl.	...	...	...	...	...	...	R.
Rhynchonella reedensis, Eth.	...	R.	R.	R.	R.R.	R.C.	C.
Rhynchonella cuvieri, d'Orb.	R.C.	R.C.	R.C.	...	...	...	...
Pecten cretosus, Defr.	...	...	...	...	R.	...	R.
Spondylus latus, Sby.	...	...	...	...	R.	R.	R.
Spondylus dutempleanus, d'Orb.	...	...	R.	R.	...	R.	R.
Lima hoperi, Mant.	...	...	...	...	...	R.	R.
Lima (?) *granosa*, Goldf.	...	...	...	...	R.	...	...
Ostrea vesicularis, Lam.	...	R.	R.	R.	R.R.	R.C.	C
Ostrea hippopodium, Nils.	...	...	R.	R.	...	...	...
Ostrea wegmanniana, d'Orb.	...	...	...	...	R.	R.C.	C.
Ostrea proboscidea, d'Archiac	...	R.R.	C.	...	...	...	...
Plicatula sigillina, Woodw.	...	...	R.R.	R.	R.C.	R.C.	C.
Inoceramus brongniarti, Sby.	...	C.	R.C.	...	...	...	...
Inoceramus lamarcki, Park.	R.	C.	R.C.	...	...	...	...
Inoceramus cuvieri, Sby.	...	C	C.	C.	C.	C	C.
Inoceramus mytiloides, Schl.	C.	...	...	...	...	...	...
Inoceramus lingua, Goldf.	...	...	...	...	...	R	C.
Inoceramus cf. *undulatus*, Mant.	...	...	...	...	...	...	R.
Inoceramus sp.	...	...	...	...	...	...	R.
Inoceramus cf. *cuneiformis*, d'Orb.	...	...	...	...	...	...	...
Avicula tenuicostata, Roemer	...	...	...	...	...	...	R.R.
Pleurotomaria sp.	...	...	...	...	...	...	R.
Ammonites (?) *leptophyllus*, Sharpe	...	...	...	...	...	...	R.
Ammonites (?) *pseudo-gardeni*, Schlüter	...	...	...	...	R.	...	...
Ammonites sp.	...	...	...	...	R.	...	...
Nautilus sp.	...	...	...	...	...	...	R.
Hamites sp.	...	...	...	...	...	...	R.C.
Scaphites binodosus, Roemer	...	...	...	...	...	...	R.C.
Scaphites inflatus, Roemer	...	...	...	...	...	...	R.R.
Scaphites sp.	...	...	...	...	...	...	R.R.

LIST OF FOSSILS FROM THE YORKSHIRE COAST.—*Continued.*

	Zone of *Rhynchonella cuvieri.*	Zone of *Terebratulina gracilis.*	Zone of *Holaster planus.*	Zone of *Micraster cor-testudinarium.*	Zone of *Micraster cor-anguinum.*	Zone of *Marsupites.*	Zone of *Act. quadratus.*
Aptychus sp.	...	...	...	...	...	...	R.
Actinocamax granulatus, Blainv.	...	...	...	...	C.	C	C.
Actinocamax verus, Miller	...	...	...	...	R.	R.	R.
Scalpellum maximum, Sby.	...	...	...	...	R.	...	R
Balanid	...	...	...	...	R.	...	...
Mosasauroid vertebræ	...	...	...	...	...	...	R.
Ptychodus...	...	R.	...	...	...	...	...
Oxyrhina mantelli, Ag.	...	...	...	...	R.	...	...
Lamna appendiculata, Ag.	...	...	...	...	...	R.	R.
Notidanus microdon, Ag.	...	...	...	...	...	R.	...



R.c. = *Rhynchonella cuvieri* zone. ∴∴—Drifts.



…E IN THE PITS ON THE LINE OF SECTION.

ANNUAL GENERAL MEETING.

FRIDAY, FEBRUARY 5TH, 1904.

H. W. MONCKTON, F.L.S., F.G.S., President, in the Chair.

Messrs. H. Kidner and H. M. Morgans were appointed Scrutineers of the ballot.

The following report of the Council for the year 1903 was then read:

THE numerical strength of the Association on December 31st, 1903, was as follows:

Honorary Members	15
Ordinary Members—	
a. Life Members (compounded)	164
b. Old Country Members (5s. Annual Subscription)	3
c. Other Members (10s. Annual Subscription) .	407
Total	589

This shows a decrease of nine as compared with the corresponding figures for the previous year.

During the year twenty-one new members were elected.

The Council regret that the Association has lost eight members by death: John Allen Brown, William Henry Corfield, Walter D. Crick, Robert Etheridge, Rev. W. B. Galloway, Charles T. Mitchell, Richard D. Poppleton, and William Vicary.

John Allen Brown was elected a member of the Association in 1883. In the same year he read a paper before the Association on "Evidence of Ice Action at Ealing." Subsequently he contributed several other papers to the PROCEEDINGS, and on several occasions conducted excursions to different parts of North-West Middlesex. Residing as he did for about forty years in Ealing, he made the Post-Pliocence deposits of that part of the Thames Valley his especial study, and was a keen student of early man and his implements. His principal work, "Palæolithic Man in North-West Middlesex," was issued in 1887. He died on September 24th last at the age of seventy-two.

Walter D. Crick was an enthusiastic field naturalist in the departments of Geology and Conchology, and a keen collector of fossils. As a speciality he took up the study of the Foraminifera, and, in collaboration with Mr. C. Davies Sherborn, published two papers on the Foraminifera of Northamptonshire. He was elected a member of the Association in 1886, and on several occasions has acted as a Director of Excursions in conjunction

GEOLOGISTS' ASSOCIATION.

FOUNDED 1858.

THE OBJECT of the Association is to facilitate the study of Geology and its allied Sciences.

THE ASSOCIATION consists of Ordinary and Honorary Members.

ORDINARY MEMBERS are elected on a Certificate of Recommendation, signed by two or more members, one of whom must have personal knowledge of the Candidate. The certificate is read at a monthly meeting, and the Candidate submitted for election at the succeeding Meeting.

Ordinary Members pay an Admission Fee of 10s.; and an Annual Subscription of 10s., or a Composition Fee for the latter of £7 10s. (£5 5s. if elected before November, 1893).

LADIES AND GENTLEMEN are eligible for election.

HONORARY MEMBERS (limited to 20), consisting of persons who are eminent in Geological Science, or who have rendered some special service to the Association, are elected, on the recommendation of the Council, at the Annual General Meeting.

THE COUNCIL, in which the management of the affairs of the Association is vested, is elected annually, and is composed of a President, four Vice-Presidents, a Treasurer, one or more Secretaries, an Editor, a Librarian, and twelve other Members.

MEETINGS are held at University College, Gower Street, W.C., on the first Friday in each month from November to July inclusive. Two visitors may be introduced by each Member. The chair is taken at 8 p.m. (7.30 p.m. at the Annual Meeting).

FIELD EXCURSIONS and Visits to Museums and other places of Geological interest are made at various dates, principally between March and August.

THE LIBRARY is deposited at University College, Gower Street, W.C., and is accessible to Members from 9 a.m. to 5 p.m. On the evenings when the meetings are held the library is also accessible from 7 to 8. Members to whom these hours are inconvenient can have books sent to them by post upon application to the Librarian, University College. Members are entitled to borrow one volume at a time, which may be retained one month. Members of the Association are permitted to consult all books in the Science Library of University College. They are also permitted to borrow books from this Library subject to the approval of the College Librarian.

THE PROCEEDINGS AND MONTHLY CIRCULARS are forwarded post free to all Members whose addresses are known, and who are not in arrear with their subscriptions.

Forms of proposal for Membership, and any further information, may be obtained by application to the Secretary,

PERCY EMARY, F.G.S.,

43, *Moray Road,*

Tollington Park, N.

Vol. XVIII. 1904. Parts 5 and 6

PROCEEDINGS

OF THE

Geologists' Association.

EDITED BY

J. ALLEN HOWE, B.Sc., F.G.S.

(Authors alone are responsible for the statements in their respective Papers.)

Contents.

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Captain A. W. STIFFE, F.G.S.
W. WHITAKER, B.A., F.R.S., F.G.S.
A. SMITH WOODWARD, LL.D., F.R.S., F.L.S., F.G.S., F.Z.S.
A. C. YOUNG, F.C.S.

(*Continued on page 3 of the Cover.*)

EXCURSION TO FELDAY, HOLMBURY HILL, AND THE HURTWOOD.

JUNE 20TH, 1903.

Director: R. S. HERRIES, M.A., F.G.S.

Excursion Secretary: E. W. SKEATS, D.SC., F.G.S.

(*Report by* THE DIRECTOR.)

THE day turned out fine after an unpromising morning, but as it followed a week of almost continuous rain, of a character hitherto unrecorded in or near London during the summer months, only a small number of members assembled at Charing Cross for the 9.24 train. On arrival at Gomshall Station at 10.59 the fine section of Folkestone Sands in the adjoining railway cutting was pointed out.

Avoiding the field-paths as too wet, the party proceeded by road through Abinger Hammer, beyond which the pebbly-series associated with the Bargate Beds was seen by the side of the road. Turning south at Crossways Farm the gravel pit visited by the Association on the excursion to Abinger, under the leadership of Mr. Leighton, was inspected (*Proc. Geol. Assoc.*, vol. xiii, p. 163). This is a gravel of the existing River Tillingbourne, and is noticeable for being composed almost entirely of greensand materials, chalk-flints being very scarce. Proceeding to Raikes Farm, the steep and deeply-cut lane, known as Raikes Hollow, was descended, and the fine sections afforded by the sides were examined. These were fully described by Mr. Leighton in the report of the excursion already mentioned, suffice it to say that the Bargate Beds are probably represented in the upper part of the section, and the sandstones of the undisputed Hythe Beds in the lower part. The road was continued up the valley towards Felday (now officially called Holmbury St. Mary), and shortly before reaching the village a cart road was followed up the hill on the west side of the valley to a stone quarry, where the beds worked consist of sandstones and sandy partings, quite unfossiliferous. This is the southern character of the Hythe Beds in this district, and though little or no chert was seen in this quarry the beds are otherwise similar to those at Leith Hill and those seen later in the day at Holmbury Hill and Pitch Hill. The exact relationship of these beds to those in the more northerly part of this district, where so wide an area is occupied by the lower greensand, is difficult to determine, but they would seem to be lower than the beds at Raikes Hollow, and farther west, near Chilworth, Dr. Gregory considered that he had established a succession (*Proc. Geol. Assoc.*, vol. xiv, p. 120).

GEOLOGISTS' ASSOCIATION.

Dr. Income and Expenditure for the Year ending Dec. 31st, 1903. Cr.

Dr.	£	s.	d.
To Balance from 1902	98	5	1
„ Life Compositions	22	10	0
„ Admission Fees	12	10	0
„ Annual Subscriptions	184	16	0
„ Dividends on Nottingham Corporation Stock ...	31	14	9
„ Sale of Publications	9	13	11
„ Sale of "Record"	1	13	6
„ Sale of "Paris Basin"	0	4	2
	£361	7	5

Cr.	£	s.	d.
By Printing "Proceedings"	88	10	11
„ „ Monthly Circulars	17	17	0
„ Miscellaneous Printing	3	8	0
„ Illustrating "Proceedings" and Circulars ...	37	3	10
„ Postage, Telegrams and Messages	37	3	5
„ Addressing	7	7	0
„ Library (including Honorarium to Librarian of St. Martin's Library)	13	11	8
„ Attendance, Lighting, Lantern, etc., at Evening Meetings	18	15	0
„ Excursions	10	12	8
„ Insurance	2	15	0
„ Stationery	1	15	6
„ Miscellaneous Expenses	0	1	2
„ Balance at Bank of England, Dec. 31st, 1903 ...	122	6	3
	£361	7	5

We have compared the above account with the vouchers, and find it correct.
We have also verified the investment of £1,108 14s. 5d. Nottingham Corporation Stock.

January 18th, 1904.

G. E. DIBLEY, } *Auditors.*
H. A. ALLEN, }

The Council think that the aim should be to hold invested funds equal to at least £7 per living compounder, the compounding fee being £7 10s., and they propose from the balance now in hand to invest the sum of £40.

The PROCEEDINGS for the year have been issued in three parts, which form the commencement of the eighteenth volume. They comprise one hundred and ninety-two pages of text, sixteen plates, and eleven figures.

The thanks of the Association are due to the several authors for their communications; and also to the Council of the Geological Society and the editors of the "Geological Magazine" for their courtesy in granting permission to use certain blocks and clichés employed for the illustrations of these parts of the volume.

The Library continues to grow in a satisfactory manner, many valuable additions having been made to it during the year.

The books previously deposited at St. Martin's Public Library have been transferred to University College, the whole of the Library being now under one roof. It is hoped that this will facilitate its use by members; and the Council take this opportunity of recording their appreciation of the new arrangement, which they trust will prove mutually advantageous to the members of the Association and to the College.

It having been found inconvenient to issue books after 5 p.m. on those days when the Association does not meet, the Council are endeavouring to arrange for books to be sent to members who desire it, and are not able to apply personally for them at the College, before the above-mentioned hour.

The following is a list of the papers read at the evening meetings:

"The Recent Geological History of the Bergen District of Norway," being the address of the President, H. W. MONCKTON, F.L.S., F.G.S.

"The Zones of the Upper Chalk in Suffolk," by A. J. JUKES-BROWNE, B.A., F.G.S.

"The Geology of North Staffordshire," with special reference to the Whitsuntide Excursion, by WHEELTON HIND, M.D.

"The Zones of the White Chalk of the English Coast: IV—Yorkshire," by ARTHUR W. ROWE, M.B., M.S., M.R.C.S.

"The Geology of Lower Tweedside," with special reference to the Long Excursion, by J. G. GOODCHILD, F.G.S.

Lectures were delivered by J. S. FLETT, M.A., D.Sc., on "A Visit to St. Vincent and Martinique"; by A. SMITH WOODWARD, LL.D., F.L.S., F.G.S., on "The Pliocene Bone Bed of Concud, Teruel, Spain"; by WALCOT GIBSON, F.G.S., on "The Coal Measures of North Staffordshire"; by LL. TREACHER, F.G.S., on "Some Flint Implements from Reading and Maidenhead"; by the PRESIDENT, on "Photographs of Norwegian Glaciers taken by Mr. J. Rekstad, of the Geological Survey of Norway," and on "Land, Freshwater and Estuarine Deposits (with special reference to recent excursions)."

The thanks of the Association are due to all these gentlemen.

During the past season one museum visit, twelve Saturday, and the usual Easter, Whitsun, and long excursions have been successfully carried out. The following is a list of dates, localities, and directors:

DATE.	PLACE.	DIRECTORS.
March 21	Grays	T. J. Pocock, F.G.S.
March 28	British Museum (Natural History) Mineralogical Galleries.	G. Prior, M.A.
April 10 to 14 (Easter)	Salisbury and the Vale of Wardour	Rev. W. Andrews, M.A., F.G.S., and H. P. Blackmore, M.D., F.G.S.
April 25	Loampit Hill and Horniman's Museum	A. E. Salter, D.Sc., F.G.S.
May 2	Kew Gardens and Museums	Professor Judd, F.R.S., and C. B. Clarke, F.R.S.
May 9	Erith and Crayford	W. Whitaker, F.R.S., and A. E. Salter, D.Sc., F.G.S.
May 16	Royston	H. B. Woodward, F.R.S.
May 23 (Cycling)	Berkhampstead to Tring	J. Hopkinson, F.G.S.
May 30 to June 2 (Whitsuntide)	Stoke-upon-Trent	Wheelton Hind, M.D., F.G S., R. F. de Salis, F.G.S., and Walcot Gibson, F.G.S.
June 6 (Cycling)	Farnborough	H. W. Monckton, F.G.S.
June 13	Uxbridge	J. Allen Howe, F.G.S.
June 20	The District South of Gomshall	R. S. Herries, F.G.S.
June 27	Sevenoaks	P. A. B. Martin.
July 4	Kelvedon	T. V. Holmes, F.G.S.
July 11	Cudham and Wallingford	H. J. Osborne White, F.G.S.
July 28 to Aug. 6 (Long Excursion)	Berwick-on-Tweed and Sunderland	J. G. Goodchild, F.G.S., and G. Abbott, M.R.C.S., F.G.S.

Detailed reports of these excursions will be found in the Proceedings.

An excursion in conjunction with the Geological Section of the Croydon Natural History Association was successfully carried out on April 18th, to see the re-opening of the cutting south of the New Cross (L.B. & S.C.R.) Station.

In spite of the unfavourable weather on most of the Saturdays, the attendance has been very satisfactory, no less than ten members having braved the elements on June 13th, when it rained persistently for nearly the whole day. Only on two occasions, viz., June 20th and July 11th, did the Association lose through the issuing of cheap tickets, irrespective of the numbers attending

the excursions. The sum paid from the Association funds on these days amounts in all to £1 0s. 11d.

Thanks are due to the Directors of the Excursions, also to the following for assistance and hospitality: Sir Edmund Antrobus, Messrs. James Bracher, Chas. Maudslay, J. Lilly, J. Garton (at Easter); Messrs. Samuel Jerrard and Sons, Loampit Hill; Dr. Stapf, Mr. Baker, and Mr. Worsdell, Kew Gardens; Messrs. Menzies, Boothby, Cole, Douglas, Antrobus, Wedd, and the North Staffordshire Railway Company (at Whitsuntide); Mr. R. C. Sikes, Uxbridge; Miss Spottiswoode, in Surrey; Messrs. Walter Scott and Middleton, Limited, Kelvedon; Captain Norman, R.N., and Mr. George Bolam, Berwick-on-Tweed; Mr. T. James and Mr. D. Woolacott, Sunderland. Thanks are also due to Mr. Philip Roscoe for kindly inviting the members to see his fine collection of carboniferous fossils, in connection with the Whitsuntide excursion.

Thanks are due to the Secretary of the Board of Education for the following Geological Survey Maps: England—Sheets 110 (Drift), 156 (Drift), 232 (Solid), 248 (Solid), 249 (Solid), 298 (Drift); Scotland—Sheets 25, 26, 33 and 34; and Ireland—Sheet 112 (Drift).

The management and arrangement of the excursions of the Association during the past year have been in the hands of the following Committee: Messrs. H. Bassett, H. Kidner, E. P. Ridley, A. E. Salter, E. W. Skeats, W. P. D. Stebbing, Miss Whitley, Mr. G. Young, with Miss Foley as Secretary for Excursions. At the last November Council Meeting this Committee was re-elected with the addition of Messrs. R. S. Herries and H. Walker, and the omission of Mr. H. Bassett, who resigned last September. It is recommended that the appointment of this Committee be confirmed as soon as the new Council meets.

Thanks are due to the Council of University College for the facilities they continue to offer the Association in the use of rooms for their meetings.

The changes in the House List are somewhat numerous. Mr. H. W. Monckton having filled the Presidential chair for the customary period of two years now retires from that office. The thanks of the Association are especially due to him for the care and attention he has bestowed upon its affairs. The persistency with which he has kept before the members the points of interest raised by the various excursions has considerably enhanced their value. The Association is also indebted to him for a most interesting address on "The Recent Geological History of the Bergen District of Norway," and also for several other communications already mentioned in the list of lectures given at the evening meetings.

Dr. A. Smith Woodward now retires from the Vice-Presidency, and the Council have much pleasure in submitting his name for

election as President. Mr. Sherborn retires from the Vice-Presidency and from the Council. Miss M. C. Foley retires from the office of Excursion Secretary, after having ably fulfilled the duties of that office for the last $3\frac{1}{2}$ years. The thanks of the Association are due to her for the time and attention she has given to the affairs of the Association during that period. Thanks are also due to Mr. Henry Fleck, who, for the last three years has filled the office of Librarian, and who now retires from office; and also to Mr. Piper, Mr. Stebbing, and Miss Whitley, who retire from the Council.

The names of those suggested by the Council to fill the vacant offices will be found on the ballot paper.

On the motion of Dr. A. E. Salter, seconded by Mr. G. Potter, the Report was adopted as the Annual Report of the Association.

The Scrutineers reported that the following were duly elected as Officers and Council for the ensuing year:—

PRESIDENT:

A. Smith Woodward, LL.D., F.R.S., F.G.S.

VICE-PRESIDENTS:

Rev. J. F. Blake, M.A., F.G.S.
R. S. Herries, M.A., F.G.S.
H. W. Monckton, F.L.S., F.G.S.
W. Whitaker, B.A., F.R.S.

TREASURER:

R. Holland.

SECRETARIES:

Percy Emary, F.G.S.
E. W. Skeats, D.Sc., F.G.S.

EDITOR:

J. Allen Howe, B.Sc., F.G.S.

LIBRARIAN:

Prof. E. J. Garwood, M.A., F.G.S.

TWELVE OTHER MEMBERS OF COUNCIL:

C. W. Andrews, D.Sc., F.G.S.
L. L. Belinfante, M.Sc., B. ès L.
C. Gilbert Cullis, D.Sc., F.G.S.
G. E. Dibley, F.G.S.
Henry Fleck, F.G.S.
Miss M. C. Foley, B.Sc.
Upfield Green, F.G.S.
Miss M. Healey.
F. L. Kitchin, M.A., Ph.D., F.G.S.
Arthur W. Rowe, M.B., M.S., M.R.C.S., F.G.S.
Captain A. W. Stiffe, F.G.S.
A. C. Young, F.C.S.

The best thanks of the Association were then voted to the retiring President, Members of Council, Auditors, and Scrutineers.

The President then delivered his address, entitled, "On Some Examples of the Different Types of Geological Formations, with special reference to recent excursions of the Association" (Estuarine, Lagoon, and Marine Deposits).

On the motion of Mr. E. T. Newton, seconded by Mr. Upfield Green, it was resolved that the President's address, just read, be printed *in extenso.*

ORDINARY MEETING.

FRIDAY, FEBRUARY 5TH, 1904.

DR. A. SMITH WOODWARD, F.R.S., President, in the Chair.

Frederick William Bennett, G. Crozel, Henry Dewey, F.G.S., and Albert Edward Thomas, B.A., M.B., were elected members of the Association.

There being no further business, the meeting then terminated.

THE JURASSIC ROCKS OF EAST GREENLAND.

By ETHEL G. SKEAT.

(*Read January 1st*, 1904).

Introduction.

THE Danish expedition to East Greenland, made in 1900, brought many interesting facts to light with regard to the geography and geology of that country. Various accounts have been published already, in connection with that expedition, by members of it and others, but the results obtained from the working out of the geological material are now known for the first time.

The paper by Dr. Madsen, published in a recent number of the "Meddelelser om Grönland"* and now translated into English, deals very fully with the Jurassic rocks of the district and reveals to us also many facts of far-reaching importance. An attempt has been made in the present paper to bring some of these facts to the notice of English geologists and to touch very briefly on the general bearing of these recent discoveries on our knowledge of Jurassic geography and geology.

In Jameson's Land itself both gneiss and granite occur, but the fossiliferous rocks are all Jurassic, overlaid by a Tertiary basalt, and it is with Jameson's Land that we now particularly have to do. The similarity between these rocks and the Jurassic boulders of Denmark is so striking that I shall, in the sequel, make a few observations with regard to it. I also hope to lay before you, later, the suggestion that here in East Greenland we are again approaching a short-line of that vast, shadowy western continent of Jurassic times, the nearctic continent of Neumayr, the shores of which were washed by the Arctic and Middle-European Seas.

Previous Literature.

Until recently our knowledge of the geology, and indeed the geography, of the Far North has been of a scanty and desultory character. Neumayr's map, published in 1883, marks various areas where Jurassic rocks of the so-called "boreal" type occur, and the knowledge there indicated has been ratified or supplemented from time to time by treatises on the rocks of Spitzbergen, König Karl's Land, Franz Josef Land, and by other valuable contributions to Jurassic literature.

I shall now proceed, as Dr. Madsen does in his paper, to give

* Madsen, V., 1904, On Jurassic Fossils from East Greenland, "Meddelelser om Grönland," xxix.

a brief historical summary of the actual explorations carried on in the particular part of the East Coast of Greenland, with which the paper has to do, prior to the work of the Danish Expedition of 1900.

HISTORICAL REVIEW: SCORESBY'S EXPEDITION.

The first discovery of Jurassic rocks in East Greenland was made by William Scoresby, jun.,* in 1822, and the following year he published an account of his voyage to the northern whale-fishery in the ship *Baffin* of Liverpool. The rocks themselves were more fully described in the same work by Jameson.†

Scoresby was evidently much impressed by the very great difference between Jameson's Land and the rest of Greenland. The even, undulating appearance of the coast as seen from the sea and the light colour of the rocks present a sharp contrast to the dark, rugged, mountainous profile which characterises the rest of Greenland. The famous Neill's Cliffs, which afterwards proved themselves so generous in their yield of fossils, particularly drew the attention of Scoresby; and his description of them, as supplemented on a later occasion by Bay,‡ will be of interest: "The western shores of Hurry Inlet consist of high steep cliffs, the so-called Neill's Cliffs, which begin to the south at Cape Stewart and rise gradually towards the north to a height of about 300 ft. The rocks of which the cliffs are composed are very friable and of a light brown colour. For fully two-thirds of their height they are concealed by the débris of the higher strata." Scoresby saw several varieties of rock, and mentions organic remains as occurring somewhat plentifully in a limestone; the fossils, however, were not much collected or examined at the time. Scoresby imagined the rocks to be of Carboniferous age; they are, however, Rhætic and Jurassic, as subsequent investigations proved.

GERMAN NORTH POLAR EXPEDITION.

Before proceeding to give an account of the later work done in Neill's Cliffs, it will be well to mention, in chronological order, the various discoveries made of other neighbouring Jurassic areas which led up to it. The next serious geological exploration after that of Scoresby was made nearly fifty years later by the German North Polar Expedition § to Kuhn Island, off the East Coast of Greenland, 1869–1870. The material brought back and subse-

* Scoresby, William, jun., 1823. "Journal of a Voyage to the Northern Whale-fishery." Edinburgh, 1823.

† Jameson, 1823. "List of Specimens of Rocks brought from the Eastern Coast of Greenland" Appendix No. 1 to above-mentioned work.

‡ Bay, Ed. 1896. "Meddelelser om Grönland," Hefte 19, p. 163.

§ Die zweite deutsche Nordpolarfahrt in den Jahren 1869 und 1870. Herausgegeben von dem Verein für die deutsche Nordpolarfahrt in Bremen. Zweiter Band. Leipzig, 1874.

quently examined by Toula in Vienna, showed a two-fold development of Jurassic beds in Kuhn Island. On the east coast are light-grey marls and sandstones, the fossils in which show affinities with the Jurassic rocks of Russia. On the south side are dark-coloured calcareous sandstones and shell-breccias, both containing coal-seams, these being referred to the middle Jurassic (Dogger). Between these two types of deposits are crystalline rocks, forming a lofty mountain ridge covered with glaciers. Two species of Aucella and several varieties are quoted from the east coast, and two characteristic Middle-European Jurassic forms: *Goniomya V-scripta*, Sow., and *Avicula Münsteri*, Goldf., from the south.

In 1883 Holm and Garde explored the coast of East Greenland from Cape Farewell to Angmagsalik.

Danish Expedition.

In 1891–2 the Danish Expedition under Ryder set out to explore Scoresby Sound, and once more reaching Jameson's Land proceeded up Hurry's Inlet and thoroughly investigated the structure of Neill's Cliffs, which form its coast-line on the west. Bay gave as his opinion that the structure of the cliffs is the same throughout, and therefore that a description of the strata of the southernmost point, Cape Stewart, will be typical of the whole. As Scoresby previously remarked, the cliffs weather very easily, and consequently the foreshore at Cape Stewart is strewn with fragments from the rocks above. Leading up from the foreshore is a little ravine, with a sloping floor rising gently to the plateau above, the edge of which is formed by the cliffs. In this ravine the various beds are seen, dipping at an angle of 6°, 50° W of S. They are better exposed here than along the shore, and the succes sion of strata is as follows:

1. At the base a green sandstone, not found north of Cape Stewart.

2. Next a grey, sandy clay-shale, with many fossil plants. This is seen in the valley, 160-180 feet above sea-level, and also crops out immediately below on the shore.

3. The next part of the slope is completely obscured by weathered fragments, which conceal the underlying beds.

4. Above is a very impure reddish-coloured limestone, very rich in fossils. The limestone varies very considerably in different parts. It may be sandy and unfossiliferous, or full of small pebbles sometimes rolled and sometimes angular, so that the rock is now a conglomerate and now a breccia; lastly, it may be a typical shell-breccia, crammed with fossils of Jurassic age. These variations occur near each other and pass over into each other.

The bed is 7 feet thick and occurs at a height of 186 feet above sea-level.

5. Above this is a sandy shale without fossils.

6. Next comes a sheet of basalt 10 ft. thick.

7. This is overlaid at the end of the valley by a yellow sandstone, 6 ft. thick, with a few carbonised plant remains, which forms the uppermost deposit at Cape Stewart.

Continuing along Hurry's Inlet, Neill's Cliffs get higher and higher, owing partly to the position of the beds, but probably also to the fact that other beds crop out both above and below those already mentioned.

The members of the expedition landed towards the northern end of the inlet, approximately south-west of the Fame Islands. Here the lowest bed exposed was a flaggy sandstone with, once more, the fossiliferous limestone above. The limestone in this exposure is pure towards the middle, but conglomeratic or brecciated upwards and downwards. Not far, but yet not immediately above this limestone is the basalt again, which here appears at a height of 1,300 ft., with alternating layers of sandstone and dolerite above. Several beds which are seen here belong to a higher horizon than those of Cape Stewart, and farther inland yet newer deposits occur. The fossils obtained were mainly Lamellibranchs and Brachiopods; many were new species, but certain typical Middle-European forms, namely *Avicula Münsteri*, cf. Goldf., *Limea duplicata*, Sow., *Ostrea sandalina*, cf. Goldf., were interspersed among them, the former in large numbers. These species are of Middle Jurassic or Callovian age, and the fauna is altogether characteristically Callovian; moreover it has close affinities with the Middle European type. Lundgren,* who examined the fossils collected on this occasion, identifies the Cape Stewart beds with the Callovian of Kuhn Island; the lowest shales containing plant-remains were proved by Hartz to be of Rhætic or Rhætic-Lias age.

Swedish Expedition.

In 1899 the Swedish expedition under the leadership of Nathorst† made a series of most careful observations all along the coast from Scoresby Sound to Shannon Island near Kuhn Island. This expedition adds to our knowledge two new fossil localities and a great deal of general geological and geographical information.

With regard to the first of these:

1. Near Point Constable, on the western shore of Hurry's

* Lundgren, B., 1895. "Meddelelser om Grönland," Hefte 19, 1896.

† Nathorst, A. G., 1901. "Bidrag till Nordöstra Grönlands Geologi." Geol. Fören. i Stockholm Förh. Bd., 23.

Inlet, a certain rock was found at a height of 231 metres; this yielded once more Rhætic plant remains, and above it, at a height of 514 metres, was seen a yellow sandstone with numerous Ostreas and Belemnites.

2. A certain region was indicated on the south-west side of Davy's Sound at Antarctic's Harbour, as doubtfully of Jurassic age. The appearance of the rocks, whose gentle outline forms a remarkable contrast to that of the Silurian and Devonian rocks hard by, is entirely in keeping with this theory; moreover, the rocks to the east of the harbour have been found to contain obscure plant remains. This spot is immediately north of Jameson's Land, very slightly west of Hurry's Inlet, and probably these deposits may be a direct continuation of those of Neill's Cliffs.

The geographical observations made by Nathorst's expedition are shown on the map in his paper. The part to the south has been revised at a later date. Nathorst's paper contains beautiful photographs of the pointed, craggy, Silurian rocks of King Oscar's Fiord, and the bold, bastion-like, in part horizontally-deposited, Silurians of Franz Josef's Fiord. The gentle outlines of the Jurassic rocks are not shown in this paper. On comparing the old coast outline with the new, we notice extraordinary differences in the coast contours. Several islands have moved, some have disappeared or become mainland, Fleming Inlet has shrunk, and King Oscar's Fiord has enormously increased. Saddest of all, "Geographical Society's Island" seems to have sacrificed its individuality, and become partly or wholly merged in that of two other islands of lesser name and fame.

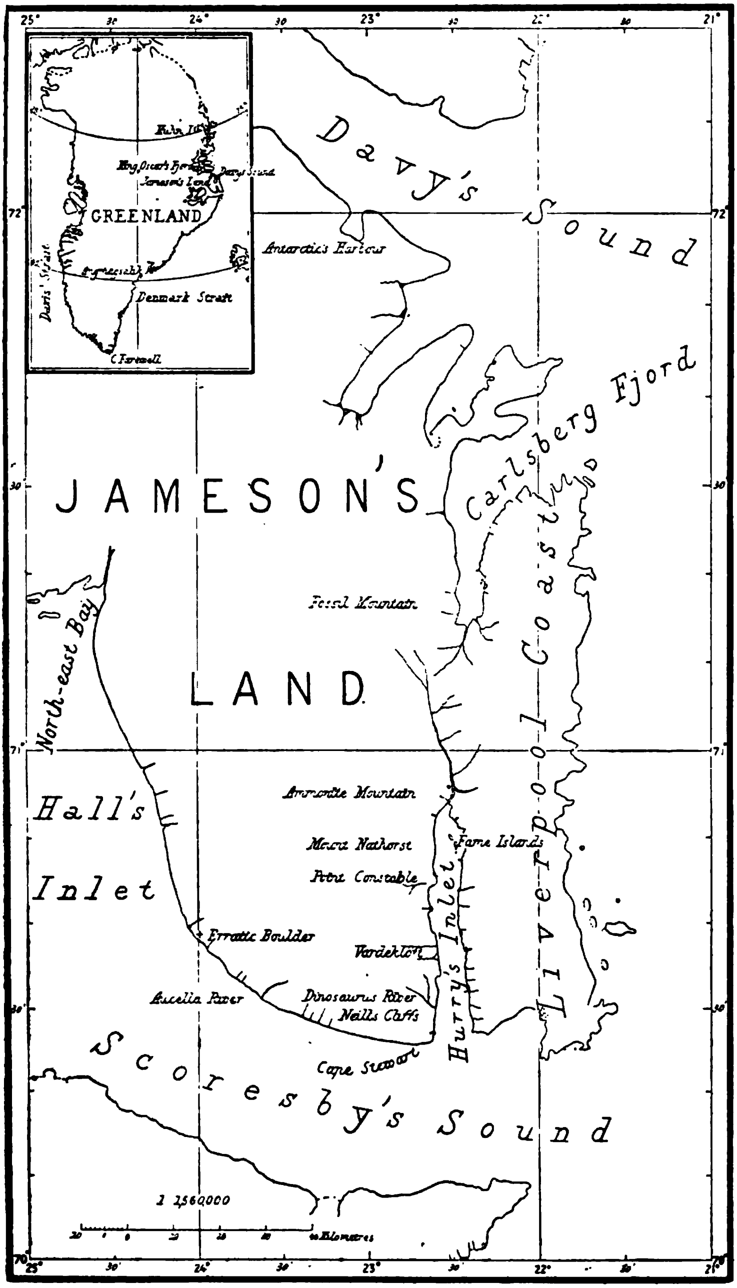
Geological Structure.

We glean now, for the first time, a splendid general idea of the geological structure of the region from Nathorst's Geological Map, which accompanies his paper. Setting aside all minor complications and foldings, we have here a succession of beds striking north and south, the oldest on the west and the youngest on the east, and a reappearance of the oldest beyond the newest to the east. If it were not for that last fact, we should imagine we had here the limb of a huge anticlinal with a core of crystalline rock. For, towards the interior we see—

1. Crystalline rock (the Urberg) consisting of granite, gneiss, and quartzite.

2. Then comes a broad belt of Silurian with possibly some Cornbrash, which extends along the western side of King Oscar's Fiord.

3. Then Old Red Sandstone, forming Traill's Island, Geographical Society's Island and Ymer's Island, along the east coast of King Oscar's Fiord.



(Reproduced by kind permission of Dr. V. Madsen.)

4. East of this, but exposed only south of King Oscar's Fiord (except for Kuhn Island, much farther north) are the Keuper, Rhætic and Jurassic.

5. The outer coast is fringed with younger eruptive rocks, probably of Tertiary age.

6. Then in Liverpool coast once more we see the Urberg cropping out, showing that we have here to do with, not one limb of an anticlinal, but probably an uneven ridged-up floor of ancient crystalline rock with newer rock in the hollows between the ridges.

We must then suppose that the whole of Greenland is, as Nathorst suggests, a "horst," or a part which has buckled up in the huge strain and stress of earth-foldings, and that the sedimentary deposits, which may once have covered the whole, are now preserved only in the long trench-like depressed areas along the coast, or where protected by younger eruptives.

Danish Expeditions of 1898 and 1900.

We pass from an account of Nathorst's work to that of the Danish Expeditions of 1898 and 1900,* both under the leadership of Lieutenant Amdrup, whose desire was to connect the work of Holm and Garde with that of Ryder. The palæontological and other investigations contained in Dr. Madsen's work are the direct outcome of the second of these expeditions. The expedition moved in two detachments, Hartz conducted part of it by sea, whilst Amdrup, who was chief in command, accomplished a perilous journey by land along the coast to Angmagsalik. The expedition started in the summer, as its object was not to traverse long distances and cover large tracts of country, as Nansen did in his first crossing of Greenland, but rather to make out as far as possible the geological conformation and structure of the region. One's preconceived idea of Greenland is that of a region perennially ice-covered, with scattered "nunnatakkr" from which the mountain-tops peep forth. This does not, however, apply to the coast, which is ice-free, the great ice-sheet extending only as far as is shown on the map. From the coastland the snow disappears in summer, except on the mountain-tops. The region with which we are more immediately concerned, namely Jameson's Land, is practically snow-free in summer, except for small pockets of snow which may remain in sunless spots from one winter to the next. In the northern part, however, are small glaciers which are not shown on the map, and in Liverpool coast there are some permanent glaciers, as the map indicates.

Hartz's detachment landed on July 31st, one and a quarter

* See papers by Amdrup, Hartz, Koch, &c.; also photographs taken by Amdrup, in the "Meddelelser om Grönland,' Hefte 27. The volume contains a French summary by M. Charles Rabot.

Danish miles to the north of Cape Stewart, near a river which since has received the alarming name of Dinosaurus River, from the footprint of a Saurian found on a loose block near it. Lamellibranchs and Belemnites were also found in blocks, supposed to have been derived from a sandstone bed exposed in the cliff at a height of about 600 feet. Loose blocks were found on the shore below, containing many beautiful specimens of *Pecten Stewartianus.*

Two members of the party, Deichmann and Nordsenskjöld, then spent five days in making an expedition into the interior of the northern part of Jameson's Land, and reported on their return that the inland plateau which they had visited was strewn with innumerable Ammonites, specimens of which they brought back with them.

Ammonite mountain yielded a specimen of *Macrocephalites* in a brown clay-ironstone, which, though a new species, is undoubtedly Callovian.

Fossil mountain farther north, west of the extremity of Carlsberg Fiord, contained a possible *Simbirskites* in light-coloured sandstone, the beds thus proving to be of Upper Jurassic or Cretaceous age. Similar beds seemed to crop out in Antarctic's Harbour to the north.

Two days later Koch and Hartz set sail for Point Constable. They observed in Nathorst's Fjord a huge oyster bed at a height of 510 metres, probably the one previously mentioned by Nathorst. It contained many fine oyster-shells, also other Lamellibranchs and Belemnites. Above was a sandstone with Crinoids. This was the most important locality of all, and yielded most determinable fossils.

The next locality visited was the one where Ryder's expedition landed in 1891 and which was described above as approximately south-west of the Fame Islands. The locality is called Vardeklöft and is a cleft or valley, as its name implies. In the lower part of the valley, 600 feet above sea-level, many plant-remains were found. Three days were spent in collecting specimens from this locality, which were afterwards determined by Hartz. Above these deposits on the north side of Vardeklöft, Hartz found many fine Ammonites and some Belemnites in a micaceous clay-shale which weathered very easily.

From August 15th to August 21st was spent in exploring the west coast of Jameson's Land from North-East Bay to Cape Stewart, thus almost completing the circuit. In the south-west of Jameson's Land, not far west of Cape Hooker, a light-coloured Aucella-bearing sandstone was seen to be cropping in a river-bed. The position of this important locality is fixed by that of the "Erratic boulder," a well-known landmark to the north-west of it, and the river has been given the name of Aucella river to commemorate the discovery. Further more exact topographical

details are given by J. P. Koch in his account of the expedition published in the "Meddelelser om Grönland" during 1902.

PALÆONTOLOGY.

We now come to Dr. Madsen's special work, which consisted in the determination of the fossils brought back by the members of the 1900 Expedition, and the classification of the rocks from the results thus obtained. The work was entrusted to him by the Carlsberg Committee in Denmark, and, from the very careful way in which he chronicles his results, one rejoices to feel that the work should have been given into such good hands.

A list of the fossils and a summary of the remarks made on them by Dr. Madsen will be given here. Figures of most of them will be found in the works of Dr. Madsen and Dr. Hartz, to which reference has already been made.

In the fossil-plants found at Cape Stewart and Vardeklöft both the Ferns and Gymnosperms are represented. The following genera and species were determined by Dr. Hartz:*

Three species of Ferns—
- *Cladophlebis Roesserti* (Presl.) *grönlandica*.
- *Cladophlebis Stewartiana*, Hartz.
- *Todea Williamsonis*, Brongn., sp.

Three species of Cycads—
- *Pterophyllum subæquale*, Hartz.
- *Ptilozamites*, sp. ?
- *Anomozamites* cf. *inconstans*, Goepp, sp.

Three species of Conifers—
- *Baiera hermælini*, Nath. M.S.
- *Stachyotaxus septentrionalis*, Agardh, sp.
- *Palissya*, sp.

All are of Rhætic-Lias age. The conifers show the coming in of drier climate conditions.

The fauna of the overlying Jurassic beds is given us by Dr. Madsen:

1. From the locality discovered first by Nathorst and described by him as north of Point Constable, visited later by Koch and Bay and then called Nathorst Fjæld, now Mount Nathorst, were obtained:

Pentacrinus cf. *Andreæ*, de Lor. These are obviously fragments of Crinoid-stems, and the pentagonal cross-section shows that they belong to the genus *Pentacrinus*. One specimen shows depressions at the sutures, characteristic of *Pentacrinus cristagalli*, Quenstedt.

* See Hartz, N 1896, "Meddelelser om Grönland," Hefte 19, for description and plates of fossils.

Myoconcha grönlandica, n. sp. This is probably identical with a Myoconcha from Cape Stewart which could not be determined.

Trigonia undulata, Fromherz. A well-known species from the Bathonian of Boulogne, and Great Oolite to Cornbrash of England.

Astarte cf. *elegans*, Sow., is broader and more convex than the Great Oolite type fossil, but comes much nearer to a specimen from Inferior Oolite of Gloucestershire.

Tancredia cf. *angulata*, Lycett. The specimens are larger than the type and show but faint indications of the groove from the umbo to the posterior end. This form has been quoted from a slightly lower horizon than most of the other fossils from this locality, *i.e.*, Lower Bajocian (Inf. Oolite) rather than Bathonian (Great Oolite).

Pholadomya angustata, Sowerby. A form occurring from the Murchisonæ-zone at base of Inferior Oolite up into Oxford Clay.

Gresslya gregaria (Zieten), Goldfuss, sp.

Gresslya abducta, Phillips.

Gresslya peregrina, Phillips.

All these Gresslya forms occur in the Humphresianum-zone, *i.e.*, the Upper part of the Inferior Oolite in Germany and England, also above this zone and the third also below it. These fossils, mentioned above, all came from the brown sandstone of Mount Nathorst.

Immediately below, in the oyster-bank, were :

Ostrea eduliformis, Schlotheim, and a more convex variety, resembling in some respects *Ostrea explanata*, Goldf.

2. From the second locality, that of Vardeklöft, on the west side and half-way up Hurry's Inlet, not far south of the last-mentioned locality, were obtained :

Astarte Hartzi, n. sp., which Lundgren found first at Cape Stewart.

Astarte Bayi, n. sp., also found at Cape Stewart. Lundgren classifies the Cape Stewart beds as Callovian and consequently the beds at Vardeklöft are Callovian also. Subsequently, a specimen of *Macrocephalites Ishmæ*, Keyserling, was found in a micaceous clay-shale at Vardeklöft. The specimens, though crushed, are identifiable with those of Keyserling from Petchora-land and thus the Callovian age of the deposits is even more definitely established. Another Ammonite found in this locality was *Cadoceras crassum*, n. sp., nearly allied to *Cadoceras Elatmæ*, Nikitin. A full description of this new form, and a diagram of the suture-line is given in the text of Dr. Madsen's work.

3. Another Callovian locality was discovered on Ammonite Mountain, north of Mount Nathorst. Here was found *Macrocephalites Pompeckji* n. sp., a clay-ironstone cast of a form nearly

allied to *Macrocephalites Ishmæ*, Keys. It differs from that species, however, in having a wider umbilicus and less embracing whorls.

4. The only definitely Upper Jurassic locality is that in the south-west of Jameson's Land, south-west of Vardeklöft. Here, between Cape Hooker and the Erratic boulder, is the little Aucella River. Hence came:

Aucella Pallasii, Keyserling, found actually in place.
Pecten, sp.
Astarte Sæmanni, de Loriol.
Casts of *Pleuromya* and *Tancredia*.

This Aucella is a characteristic fossil of the lowest Virgatus beds of the Lower Volgian of Russia, equivalent about to the Middle Portlandian of Boulogne or the Upper Kimeridge Clay to Portland Sand of England. *Astarte Sæmanni*, de Lor., is the most characteristic and beautiful species of the Danish boulders of Kimeridge to Portland age.

A species of *Perisphinctes* was also found in a loose block in Aucella River. The specimen shows only the inner whorls, but these resemble those of *Perisphinctis Panderi*, d'Orb., as described by Michalski from the Lower Volgian of Russia. This form also belongs to the Lower Virgatus-zone near Moscow and occurs there at about the same horizon as *Aucella Pallasii* and *Astarte Sæmanni*.

5. Another possible Upper Jurassic locality is known in Fossil Mountain, and depends on the identification of an *Olcostephanus*. Professor Pompeckj believes this to be a new species of the genus *Simbirskites*, as established by Pavlow and Lamplugh.

Age of the Deposits.

This brings us to the close of the Palæontological part of the memoir, and it now concludes with a few general remarks on the position and age of the deposits. We may summarise these as follows:—

(i.) Our knowledge of the Callovian beds has been very considerably extended, for, whereas before this expedition there was only one Callovian locality known, namely, that of Cape Stewart, we now know of three more and, what is far more important, the characteristic Ammonite forms have been discovered. The new Callovian localities crop out in a straight line north and south along the west coast of Hurry's Inlet and are:—

1. $1\frac{1}{4}$ Danish miles north of Cape Stewart.
2. Vardeklöft, a valley half-way up the inlet.
3. Ammonite Mountain, a locality at northern extremity of the inlet.

These beds are in close petrological and faunistic connection with the Cape Stewart beds and are probably a direct continuation of those.

(ii.) On Mount Nathorst at the north-west extremity of the inlet, north of Point Constable, a rich Lamellibranch fauna has been discovered in beds clearly older than Callovian, but above the horizon of the Rhætic-Liassic plant-beds. These beds, by their fossil-contents, are proved to be of upper Bajocian to Lower Bathonian age.

(iii.) On the south-west of Jameson's Land, in the river named from the fossils found there: Aucella, we have certain evidence of the existence of the "white Jura" or Upper Jurassic, approximately of Upper Kimeridge to Portland age. *Aucella Pallasii* is characteristic of the Volgian beds near Moscow, which belong to this horizon and *Astarte Sæmanni* is another characteristic species of the Boulogne area.

The occurrence of *Simbirskites* in the north, at Fossil Mountain, points to a continuation of these higher beds in that direction. The same beds occur possibly at Antarctic's Hafen. Pompeckj has already identified all these same beds in König Karl's Land* and Franz Josef Land.†‡

Possible Distribution of Land and Sea during Jurassic Times.

The most interesting question which can arise with reference to an entirely new area always is: how does it fit in with or necessitate a reconstruction of our preconceived views with regard to the geography of the period? Taking as a basis Neumayr's map of the distribution of land and sea during Upper Jurassic times, we find that all our observations relative to East Greenland seem to help us to a more accurate determination of the position of the north-east shore-line of the great Nearctic Continent. We certainly have here to do with coast-deposits, as the large amount of detrital matter in the beds and the predominance of shallow-water forms clearly show. We might perhaps be inclined to shift the coast-line slightly farther east, but it would take the same direction as it does in Neumayr's map.

In order now to give a very general idea of the changes that affected this area during Jurassic times we must consider the distribution of land and sea, as indicated in the maps of de L'Apparent and Neumayr.

L'Apparent's map of the Upper Trias indicates what we believe to be the case, namely, that East Greenland was part of a gradually

* Pompeckj, J. F., 1899, Ofvers. Vetenskaps-Akad. Förh. Stockholm. No. 5.

† Pompeckj, J. F., 1899. Jura auf Franz Josef Land, Zeitsch, d. deutsch geol. Ges. Bd., 51. Heft 1.

‡ Nathorst, A. G., 1899. Fossil plants from Franz Josef Land, pp. 22-28.

silting-up area, more or less cut off from other areas, like that of Germany and north-west Europe. The evidence we have is slight but sufficient, and consists in the footprint of a large reptile and Rhætic-Liassic plant-remains.

In the period immediately succeeding this the area may have been land.

Dr. Madsen's paper now, for the first time, supplies evidence in proof of the fact that, during the subsequent period of depression and gradual submergence, the Bajocian-Bathonian sea extended to East Greenland. L'Apparent's map indicates only the eastern shores of the northern branch of this sea; in East Greenland we approach the western shore-line. Moreover, the Lamellibranch fauna shows close affinities with the Middle-European, and therefore these parts of the sea must have been connected. Neumayr connects them later by his so-called Shetland Strait.

With regard to the Callovian Sea, Lundgren's work connects the East-Greenland with Middle-European forms, thus showing water communication between the Arctic and Middle-European seas. L'Apparent's map seems to indicate what Dr. Burckhardt would call a very good "Wanderstrasse" for these forms, as the map is drawn with a continuous shore-line to the south. At the same time, we must note the discovery of Ammonites characteristic of the Petchora-basin for the first time in this area. Hence, we imagine there may have been sea communication between North Russia and East Greenland, perhaps round the north of the Scandinavian land-mass.

Lastly, in the Portlandian period, when the submergence reached its maximum in the north, we have even greater evidence of sea connections, probably along the same lines. The fauna of East Greenland shows affinities with those of Boulogne and South-west England, with that of the Jurassic boulders of Denmark, as also with that of the Volgian beds near Moscow.

There may have been two long gulfs or straits, as on L'Apparent's map; Neumayr's map makes one of these a broad connection and the other a very narrow strait. Whether the main communication between these seas was by the north of Scandinavia is a doubtful point, the theory being based mainly on the belief that the fauna is definitely of a boreal or Arctic type. Again, the boreal nature of the forms is now rendered an open question through Burckhardt's discovery of both Ammonites of Virgatites-group and Aucella, the so-called boreal forms, intermingled with other typically Middle-European forms in the Cordilleras. Burckhardt* considers that their occurrence depends not so much on the temperature as on the facies, and Pavlow has for some time been of the same opinion. It

* C. Burckhardt, "Beiträge zur Kenntniss der Jura und Kreideformation der Cordillere." Palæontographica Band 50, Lief. 1-3, 1903.

may be worth while in this connection to record the facts that:

In East Greenland the Aucella-bearing rock is a light-coloured sandstone, obviously of shallow-water formation, and no Virgatites-Ammonites have up to the present time been found in it. The Danish boulders and Boulogne beds are mainly limestone, somewhat impure, but clearly of deeper-water origin than the sandstone. The Danish boulders, at any rate, contain not a single specimen of Aucella, though the Lamellibranch fauna is abundant. They do, however, contain two typical Russian Virgatites-Ammonite forms.

In the Moscow basin both Ammonites of Virgatus-group and Aucellas are found, the rock being mainly of clayey material, such as would accumulate at a depth intermediate between that of the Greenland and Danish boulder-type. Much more evidence is needed before we have sufficient data to formulate a theory on this point.

A quite different circumstance to be noted in connection with the East Greenland beds is that we have at present no evidence in this area of the existence of any deposits which would bridge over the gap between Callovian and Portlandian. They may still be discovered, but if we realise how near the coast-line must have been and the shallow nature of the deposits, it will not seem unlikely that some comparatively slight displacement may have converted the region into land for that space of time.

The work that I have been doing now in translating Dr. Madsen's paper has recalled to my mind, over and over again, the time I spent in working out the Danish Jurassic boulders. Most of the conclusions I came to then, especially with regard to the Portlandian boulders, which interested me most, were embodied in the paper* published at the time, but a few have crystallised out since.

The boulders seem to me to play an important part in supplying evidence for the determination of Portlandian shore-lines. Moreover, I still feel there must be some definite distinction between Aucella-bearing and non-Aucella-bearing deposits, even though the distinction may not be one of climate, and that the Danish boulders belong to latter deposits—the East Greenland to the former. One species, that of *Astarte Sæmanni* (a characteristic Boulogne species), is common to both. At the time I spent a great deal of labour on *Astarte Sæmanni*, trying to establish some reason for the appearance in it of a pallial sinus. I then thought this might be a boreal character, as I found the same feature in a recent species from the shores of Iceland. It was not, however, present in a recent species sent me from Greenland. I was afterwards inclined to think that the greater

* Skeat, E. G. and Madsen, V. "On Jurassic, Neocomian and Gault Boulders found in Denmark." Kjöbenhavn: Danmarks Geologiske Undersögelse 2. Nr. 8.

freshness of the water in colder regions, due to melting ice, might explain this.

Again, with regard to the Danish boulders, the occurrence of Virgatus Ammonites was not the only faunistic link with the Volgian; but still more striking and remarkable was the extraordinary similarity between these rock fragments and the beds of Kimeridge to Portland age exposed along the shore at Boulogne. A visit to the collection at Boulogne only established their identity yet more closely. The nearest deposits in England are those of Swindon, and even more the Hartwell Clay, which actually resembles the Volgian in facies as well as in fauna. I will close my remarks on the Danish boulders by saying with what interest I discovered, in Burckhardt's paper of 1903, a confirmation of a conclusion I had myself arrived at after examining the Lower Portlandian boulders, but which I had not then seen definitely stated elsewhere—namely, that in certain regions there is no palæontological break between the Kimeridge and Portland deposits, but indeed that a certain horizon contains faunistic elements of both. This horizon I called, in my paper,* Kimeridge-Portland. Referring again to Neumayr's map, of Upper Jurassic continents and seas, we have seen evidence of the existence of the eastern shore-line of the Nearctic continent, and of the great Scandinavian island's southern shore-line, which formed a "Wanderstrasse" from the basin of Moscow to that of Skagerrack. We have proved to some extent the existence of a Shetland Strait, perhaps wider than Neumayr's, and the presence of another shore-line near Northern France and Southern England.

I must state, in conclusion, that the present paper does not in any way pretend to deal with the main part of Dr. Madsen's paper, which consists of a very careful palæontological treatise on the East Greenland Jurassic fauna. Neither, on the other hand, must Dr. Madsen be held responsible for the general theories stated here. This paper has been written, not with a view to the reiteration of Dr. Madsen's palæontological researches, which would not be within its scope, but in order to find out how far, in the light of these recent discoveries our ideals with regard to Jurassic land and sea distribution may be considered to be established or to require modification.

Dr. Madsen's paper is now published, and a further study of it, as also of the explorations which led up to it, will make us of one accord with M. Charles Rabot, who begins his summary of the work done by the various expeditions and scientists, with the following words:—"Le Danemark vient de terminer au Grönland une œuvre considérable qui restera un des monuments géographiques du XIXe siècle."†

* See Skeat, E. G., and Madsen, V. 1898. Quoted above.

† Résumé des communications sur le Grönland par Charles Rabot, 1902. Meddelelser om Grönland. Hefte 27, p. 355.

ON SOME EXAMPLES OF THE DIFFERENT TYPES OF GEOLOGICAL DEPOSITS.

Being an Address delivered at the Annual Meeting of the Geologists' Association on February 5th, 1904, with which is incorporated the substance of a Lecture delivered at the Meeting of the Association on December 4th, 1903.

By the President, HORACE WOOLLASTON MONCKTON, F.L.S., F.G.S.

I WAS greatly interested by a paper which Mons. E. Renevier brought before the International Geological Congress at Zurich in 1894. It was entitled Chronographe Géologique, and the sedimentary formations were separated into groups—aerial, limnal, estuarial, etc.

During the last few years the Association has visited a number of sections in a great variety of geological formations, and I have had an opportunity of considering his classification so far as it relates to our British deposits, and I think that perhaps some of my notes on the subject may interest you.

I propose to follow Renevier and to divide the sedimentary formations into the following nine groups:—

Deposits not of Marine Origin.

1. Subaerial.
2. Fresh-water.
3. Estuarine.
4. Lagoon.

Detrital Deposits formed in the Sea.

5. Coastal deposits corresponding to the Littoral, and Laminarian zones of the Zoologists and to some extent including the Coralline zone.
6. Bathial deposits corresponding to the fourth bathymetric zone of the Zoologists, and probably sometimes including the third or Coralline zone.

Organic Deposits formed in the Sea.

7. Pelagic type.
8. Coral Reefs.
9. Abyssal formations.

CLASS I.—SUBAERIAL DEPOSITS.

Blown Sand.—Of the subaerial deposits blown sand has attracted a good deal of attention in this country, for on many of our coasts it has proved exceedingly destructive. Thus the

Barony of Culbin, on the Moray Firth, has been completely covered by blown sand.

I may remind you of the extensive sand dunes which we saw on March 29th, 1902, around Penard Castle, in Gower, which extended up the rocky slope to a considerable height; and of the long ridge of blown sand on the Northumberland coast at Scremerston, where we spent August 3rd of last year.

These were both good examples of sand dunes, but those of us who attended the meeting of the British Association, at Southport, last September, saw sand dunes on a much larger scale. The foreshore there presents a wide expanse of sand at low water, and, as it dries, the wind blows the sand inshore and piles it up into dunes.

There are many sections in the dunes showing that they are well stratified and false bedded. The bedding was, no doubt, originally parallel to the surface, and as the wind changed in direction the false bedding was produced. Land shells and rabbit bones abound, and there are also many fragments of marine shells which have been blown inland. We are told that at the base of the older dunes there is a stratified deposit with *Bythinia tentaculata* and other fresh-water shells, where the sand has been blown on to marshy ground.

It has been suggested that various breccias may very probably be of subaerial origin, and that some of the finer materials may be windborne. (See Prof. Bonney, "On the Relation of Certain Breccias to the Physical Geography of their Age," *Quart. Journ. Geol. Soc.*, vol. lviii, p. 185). Possibly, the Triassic Conglomerate which we saw at Port Eynon, in Gower, at Easter, 1902, may come into this class of deposit. It did not appear to be stratified, and consisted of blocks and pebbles of limestone and chert, the different sizes mingled together. The conglomerate rested on the upturned edges of the Bishopstone Beds, which are of Carboniferous age.

Last August we saw a similar deposit between Burnmouth and Berwick-on-Tweed. It also consisted of an unstratified mass of stones of various sizes up to and, I think, at times, over three feet in diameter. It belongs to the Upper Old Red Sandstone.

Mr. Goodchild, who was our Director on the occasion, said he thought that the conglomerate was due to powerful torrential action, and he believed that the whole of the Upper Old Red Sandstone was formed during the prevalence of desert conditions, at a time when the land stood some height above sea level. In confirmation of his view, he stated that the sandstone in the formation was much false bedded, that casts of desiccation cracks and rain-pitted surfaces were common, and that he had found grains of desert sand on several horizons (*ante*, p. 119).

With regard to the Lower (Caledonian) Old Red Sandstone,

Mr. Goodchild thinks that it was also accumulated under continental conditions, and is largely due to torrential rain.*

Bone Breccia and Head.—Much of the breccia with bones found in caves should be classed with the subaerial deposits. We saw an excellent example at Bacon Hole, in Gower (Easter, 1902). There was on the floor of that cave a great pile of limestone débris cemented by carbonate of lime. Some of the material had, no doubt, fallen from the roof of the cave, but I think that the greater part had come from above through a great swallow hole, now cut through by the sea.

The angular Head, which overlies the raised beach in Gower, is a very similar deposit and is also of subaerial origin. (See *Proc. Geol. Assoc.*, vol. xvii, p. 367, fig. 55).

Perhaps I may here mention the rather extensive deposit of chalky hill-wash near Betchworth, to which Mr. Whitaker drew our attention on June 14th, 1902.

Clay with Flints.—The Clay with Flints which covers so large an area of our chalk is another subaerial deposit. It is mainly due to the decomposition of the chalk under atmospheric action.†

Sarsen Stones.—The sarsen stones of the Bagshot District and probably those found in many other places belong, in my opinion, to the subaerial deposits. I believe them to be the relics of an old land surface, as I explained on the Aldershot Excursion last summer. (See *ante*, p. 184).

Rootlet Beds, Dirt Beds, etc.—We saw a very good example of a rootlet bed in the Pakefield Cliffs on April 4th, 1893. It consisted of clay, brown at the top but blue below, and it was full of rootlets, with a flint pebble or an unworn flint here and there. There was but little sign of stratification.

Clearly this was a land surface, and it belonged to the time of the Cromer Forest Bed Series. The Forest Bed itself is of estuarine origin, but the upper surface is in many places weathered and penetrated by roots. Mr. Clement Reid thinks there may possibly be a second land surface on the top of the Weybourn Crag, beneath the Forest Bed Series.‡

Another example of a land surface is found in the Hamstead Series. The "Black Band" consists of about two feet of carbonaceous laminated clay with fresh-water shells and plant remains, and has been traced over a large area in the Isle of Wight. It rests upon a weathered surface of Bembridge Marl full of roots, and Mr. Clement Reid observes that this surface is well marked in borings, which after passing through unweathered Hamstead Beds penetrate a carbonaceous soil and then enter a

* Fauna, etc., of the Clyde Area, Brit. Assoc., Glasgow, 1901, p. 463.
† See Whitaker, Geol. of London, *Mem. Geol. Survey*, 1889, vol. i, p. 281.
‡ Geol. of Cromer, *Mem. Geol. Survey*, 1882, p. 22.

weathered clay full of roots, as in the surface soil many feet above.*

The Mammal Bed in the Middle Purbeck of Durleston Bay should, I think, be mentioned here. It is grey, earthy, about a foot thick, and from it many remains of marsupials have been obtained. I pointed it out when we were in Durleston Bay, at Easter, 1896, but none of us found any remains of mammals.

The Dirt Beds at the bottom of the Lower Purbecks are also old land surfaces. At Easter, 1889, we saw the Dirt Beds of the Isle of Portland, so well known from Lyell's illustration, showing tree-stumps and roots. And at Easter, 1898, we visited the quarries in the Purbecks and Portlands at Portisham Hill, near Abbotsbury. You may remember that we saw two large fragments of trees—one horizontal and over six feet long, the other vertical with spreading roots. We again saw one or more dirt beds close to the bottom of the Lower Purbeck, last Easter, in the quarry on the Teffont side of the Chilmark Ravine in the Vale of Wardour.

These Dirt Beds are relics of the land surface of the Purbeck Continent; a marine formation was, however, at the time in progress in East Yorkshire, and the Speeton Clay records the continuance of the sea there during the whole of the Purbeck and Portland periods.

When I gave a lecture on this subject, last December, Dr. Skeats reminded us of the quarry at Mount Sorrel, which some of our members "had an opportunity" of visiting during our Whitsuntide excursion of 1902.

Prof. Watts on that occasion drew attention to the junction of the granite with the overlying trias, showing what he felt sure was the effect of wind erosion on the granite surface before the trias was deposited upon it (*Proc. Geol. Assoc.*, vol. xvii, p. 379, and Plate xviii). This eroded surface should accordingly be placed amongst the pre-triassic land surfaces.

In the Coal Measures we have sun-cracks, marks of rain-drops, footprints, and roots *in situ*, all of which are evidence of land surfaces. The present opinion seems, however, to be that the coal seams themselves were deposited in water, for, though branching rootlets are common in the underclays, it does not follow that they are the soil upon which the coal grew.

GLACIAL DEPOSITS.—I think that several of our members will agree with me in thinking that we have seen subaerial deposits of glacial origin during recent years, but the subject is a large one, and I will not go into it this evening, more especially as it is one upon which I rather think that British Geologists are not yet quite agreed.

VOLCANIC DEPOSITS.—We have, during recent years, seen many examples of volcanic deposits. They are frequently

* Geol. of the Isle of Wight, *Mem. Geol. Survey*, 1887, p. 190.

stratified, the material appearing to have fallen into and been arranged by flowing water or currents. Volcanic eruptions are, however, often accompanied by the discharge of water, and on the whole it seems most convenient to class the volcanic deposits with the subaerial formations.

In May, 1902, during our excursion to Charnwood Forest, we saw some magnificent sections in volcanic agglomerate at the crags near Grace Dieu and Charnwood Lodge Drive. In some cases the rock seemed to consist of volcanic bombs and fragments, often of large size, buried in volcanic dust. I noticed blocks three feet across. On July 29th last we saw something of the volcanic series of the Cheviot Hills. It is of the age of the Caledonian Old Red Sandstone. We walked up the side of a small stream, the Common Burn, and saw sections in :—

1. Bedded lavas (andesites) altered in places probably by contact with the Cheviot granite.
2. Dykes and sills of porphyrite cutting through the lavas. These Mr. Goodchild thought were offshoots from the granite.
3. The Cheviot granite.

On the 28th of July we saw, at St. Abb's Head, a series of rocks which, though mapped as intrusive, are now known to be lavas. They belong to a different volcanic area to those of the Cheviots, and in this case the whole series has been cut through by the sea, giving a magnificent section.

We walked from Coldingham Shore across the low ground inland of the Head to a small cove, where we saw on the shore the Silurian greywacke, greatly folded on one side, and a bed of andesite, one of a series of lava flows, on the other side of the landing place. There are, in fact, three of these lava sheets separated by stratified tuffs and conglomerate.

You may remember the tuff in another small cove where we lunched during heavy rain. The structure of the tuff or conglomerate was very well shown in the pebbles from it which covered the beach. After lunch we, or some of us, climbed down to the shore at another place and got specimens from a dyke of lamprophyre which cuts the volcanic rocks, and was well seen at the bottom of the cliff. This volcanic series is believed to be about 1,000 feet thick.

On both these days we had a good opportunity of studying lava flows, but we only saw tuffs on a small scale. A little farther north, however, on the coast at Dunbar and North Berwick, the cliffs afford admirable sections in the fragmental volcanic formations. Up to the present we have not visited those places, but I think we might well do so some day, for I have found them of the greatest interest.

The material was probably ejected from the three large necks,

Traprain Law, North Berwick Law, and the Bass Rock. The first of these necks is formed of phonolite, and the other two of trachyte, and they themselves are well worth a visit.

The cliffs show sections in tuff and conglomerate, and in many parts the whole cliff is composed of those rocks. The blocks in the conglomerate are often very large, one seven feet across is mentioned in the memoir on Sheet 33, Scotland. In places the tuff is stratified, and here and there sedimentary beds occur. Some limestone has been worked near North Berwick, but I do not think that any marine remains have been found in it, and I fancy that the volcanic material was either thrown on to the land or into lakes or lagoons.

The blocks in the conglomerate are of igneous rock, shale, cementstone, limestone, &c. The date of the eruptions was a little before the beginning of the deposition of the Carboniferous Limestone Series.

CLASS II.—FRESH-WATER DEPOSITS.

In this class I shall attempt to include deposits in rivers down to their estuary, in inland lakes which are not salt, and marsh deposits which cannot fairly be said to be of subaerial origin.

On April 20th, 1901, we visited a remarkably fine series of sections in the recent deposits of the River Lea, between Tottenham and Higham Hill. The Report of the excursion was by Mr. A. S. Kennard, and not by myself as was stated by mistake, and I shall be glad if members will make the correction in their copy of the Proceedings (vol. xvii, p. 135).

The Alluvium at this point is half a mile wide, but it broadens out to about a mile a little to the north where a tributary stream from Epping Forest joins the Lea. The surface of the ground is very flat, with a level of about 25 feet above the sea. On the east the Alluvium is bounded by London Clay, and on the west by River Gravel, both of which rise from beneath it.

The surface was formed of a bed of silt with mud, peat, and dark clay, in places as much as ten feet thick. Below the peaty bed there was a bed of gravel, the bottom of which we did not see. This gravel was well-stratified, current-bedded, and in one place rose up nearly to the surface. Here and there a little peat occurred in the gravel.

In several places there were beds of light-coloured shell marl in the peat, and Mr. Kennard mentions that in one place he noticed a patch in the gravel. These beds of shell marl were lenticular, with a maximum thickness of about a foot. They were not all on the same horizon, and no doubt owed their position to alterations in the course of the river. The shells were of land and fresh-water species. It will be noticed that the

river had excavated a valley here. It then ceased to excavate, having, no doubt, got nearly to sea level, and began to deposit coarse material forming gravel. Finally, for reasons upon which I need not now enter, a period of repose set in, and the river has been depositing fine material and vegetable débris, and has thus formed the dark-peaty bed. A shell marl of the type found here would, in process of time, possibly be converted into a limestone.

During our Easter excursion of 1896 we visited the deposit of calcareous tufa at Blashenwell, near Corfe Castle. It is believed to be of Neolithic age, and contains many land shells. Perhaps I ought to class it with the subaerial rather than with the fresh-water deposits.

Calcareous beds of fresh-water origin form an important feature in the Oligocene Series of the Isle of Wight. At Whitecliff Bay the Bembridge Limestone is about twenty-five feet thick, and contains both land and fresh-water shells. Several specimens of *Helix vectensis* were found by members of our party at Easter, 1895. In the middle of the limestone there is about three feet of carbonaceous clay, probably of estuarine origin, as it contains *Cyrena obtusa* with the valves united. In both the Upper and Lower Headon there are beds of limestone with fresh-water shells Limnæa, Planorbis, Paludina, &c.

Mr. Hudleston has recently discovered what he believes to be a fresh-water limestone of Eocene age at Creech Barrow, near Corfe Castle.*

The Paludina-Bed, which is found in the middle of the Woolwich Series, should be classed with the fresh-water limestones. It is a calcareous stone, at times rather clayey, and is usually full of fresh-water fossils. It extends over a considerable area and has been recorded at Peckham, New Cross, and Chiselhurst.

We saw the bed exposed in the Sundridge cutting on the South Eastern Railway on July 28th, 1900. It consisted of a compact mass of Paludinæ.

It was again seen by the members of the Association in the re-opened cutting of the London and Brighton Railway at New Cross on April 18th, 1903, when Paludina, Unio, and a few specimens of *Pitharella Rickmanni* were found; and again, near Crofton Park on April 25th, 1903, where it contained merely a few specimens of Paludina. (See *Proc. Geol. Assoc.*, vol. xviii, p. 162).

The Purbeck Marble at Pevril Point, near Swanage, is a mass of the shells of Paludina, and is not unlike the Paludina Bed of the Woolwich Series on a large scale. The late Mr. Meyer considered that it had been deposited in quiet water, possibly in a lake.

* *Proc. Dorset Nat. Hist., etc., Field Club*, vol. xxiii, p. 146 (1902).

Some of the bands of limestone in the Coal Measures are probably of fresh-water origin, though I thought that our Directors at Whitsuntide seemed inclined to consider the Coal Measures less a fresh-water formation than we have usually supposed. (See Geol. of Stoke-upon-Trent, *Mem. Geol. Survey*, 1902, p. 39).

During recent years we have paid many visits to the brickfields near Crayford and Grays, and though some of the sections are not as fine as they used to be, they are still very well worth study. The deposits consist of brickearth, sand, and gravel, and contain *Corbicula fluminalis*, *Unio littoralis*, and other land and fresh-water shells.

The brickearth is usually very evenly bedded, and in places one can see that alterations in the course of the river have taken place, the stream having cut down into the bed previously deposited and produced current-bedding.

The sand and gravel is also current-bedded, and usually to a much greater extent than the brickearth.

The valley is cut in Chalk and Thanet Sand, and in places the river deposits may be seen banked up against the side of the old valley, and where the side of the valley is Chalk there is generally a good deal of chalk rubble between the valley deposit and the solid rock.

It is interesting to compare these Thames deposits with those in the buried valleys of the Yorkshire coast. Near Flamborough the old valleys are cut in Chalk, and there we find a similar chalk rubble at the sides of the valley.

The Yorkshire valleys are largely filled in with stratified sands and gravels, but as they are older than the local Boulder Clays they are partially filled in by those clays.

At Easter, in 1893, we were fortunate enough to see the fresh-water beds at Mundesley, near Cromer. The section is figured in Lyell's "Antiquity of Man," 4th Edition, 1873, pp. 268. The deposit rests in a valley cut in soft strata, belonging to the Glacial and Forest Bed Series. At the bottom there is some rather coarse gravel and upon it there is a dark bed of peat, sand, and more or less clayey silt. The thickness of this dark bed is about 30 feet. It contains roots, seeds, *Anodonta cygnea*, and other land and fresh-water fossils. Above it there is more gravel.

When we visited the locality in 1902 this part of the cliff section was hidden.

We have on two occasions recently visited the Hitchen Lake Bed (June 20th, 1896, and May 5th, 1900). It rests in a hollow cut in stratified and current-bedded gravel which is probably of Glacial age. The lake deposit consists of a soft calcareous sandy loam of various shades of brown. It is for the most part thinly and evenly stratified, and is full of shells and shell

fragments of fresh-water molluscs. There is considerable thickness of brickearth above the lake bed.

I have not seen the Hoxne deposits, but judging by the published accounts they resemble those of Mundesley and Hitchen, and like them are newer than the Glacial Deposits of the district.

The celebrated deposit at Fisherton, near Salisbury, which we saw last Easter (1903), reminded me of the Thames deposits at Crayford and Grays, and also of those in the old valleys near Flamborough, for in all these cases there is a series of beds formed by a river banked up against the side of a valley, and in all it so happens that the side of the valley is wholly or partly of Chalk.

On May 26th, 1894, we explored a series of brickfields on the high ground to the west of Luton. At a kiln south of Woodside we saw a good section showing a considerable thickness of brickearth and sand, with current-bedding in places.

At Caddington we saw other sections in well stratified brickearth, with layers of clay and of stones here and there. I think that this deposit is probably of fresh-water origin, possibly due to floods caused by melting ice during the latter part of the Glacial period.

The Sidestrand Unio-Bed between Cromer and Mundesley is a fresh-water deposit, older than the Boulder Clays of Norfolk, and belonging to the Forest Bed Series. It rests on the land surface at the top of the Forest Bed which I have already mentioned. At the bottom of the deposit is a gravel mainly composed of small subangular flints, and containing many single valves of Unio. Above there is a clayey bed with more Unio and other fresh-water shells. I believe that this bed is not often exposed, but we were fortunate enough to see it and to be able to collect from it in 1893, on the same lucky day on which we saw the Mundesley fresh-water bed. It was the first of April.

On the west of Cromer the fresh-water bed on the horizon of the Sidestrand Unio Bed consists of peat or peaty loam, often sandy at the bottom, and Mr. Clement Reid remarks that most of the small vertebrated remains and fresh-water shells for which this bed is celebrated have been obtained from Runton.

I have already mentioned the Black Band of the Hamstead Beds of the Isle of Wight as lying on an old land surface. It contains fresh-water shells, and at the bottom there is a layer with well-preserved *Unio gibbsii*. Much of the Lower Hamstead Series and, probably, some part of the Bembridge Marls is of fresh-water, perhaps mainly of lacustrine origin.

The Headon Limestones are, as I have said, of fresh-water origin, and some of the clayey beds also contain fresh-water fossils. You may remember a bed close to the bottom of the Lower Headon, in Whitecliff Bay, to which I drew your attention

when we were there on April 12th, 1895. It is a dark clay with ironstone nodules, lignite, and great numbers of Paludinæ. I consider it a typical fresh-water formation.

The light-coloured sands and pipeclays which form the Bagshot Beds at Corfe, Studland, and between Poole and Bournemouth, are probably of fresh-water origin. It is true that bored wood is found in them, but, according to Mr. Starkie Gardner, bored wood is found a long way from the sea in some modern rivers. He considers this part of the Bagshot Series to have been deposited by a large river flowing from the west.

Between Poole and Bournemouth the cliff section shows sand with many lenticular patches of clay. The clay is usually of a light colour, but dark patches occur. In many of these clay patches impressions of leaves are abundant and beautifully preserved. Several of us obtained good specimens during our excursion at Easter, 1894.

The pipeclays at Corfe are fairly extensive, but the beds are possibly lenticular. They are probably of fresh-water origin.

The Bovey Tracy Beds are of Bagshot age and appear to have been deposited in a large lake. The Association visited the sections at Easter, 1900, and the general appearance is well shown in the photograph reproduced in the Report of that excursion (*Proc. Geol. Assoc.*, vol. xvi, Pl. 12). The deposit is very thick, and a boring was carried to a depth of 520 feet from the surface, through clays, sands, and lignites, without reaching the bottom.

The greater part of the Lower Bagshot of the Bagshot district appears to be without fossils, and may be of fresh-water origin. On May 30th, 1891, Mr. Hudleston showed us a clayey deposit in this part of the Bagshot series, at Hatch, near Addlestone which seemed to be lenticular and was not unlike some of the fresh-water beds which I have mentioned.

The Reading Beds in the Reading district consist of an upper division of mottled clay some thirty feet thick, and of a lower sandy division about twenty feet thick beneath which is the Bottom-bed, consisting of green sand and clay with green coated flints resting on the chalk.

This Bottom-bed is marine and the Basement-bed of the London Clay above the Reading Series is marine too, but I believe the whole of the intervening sands and mottled clays to be of fresh-water origin.

In the sands a little above the Bottom-bed there are some lenticular patches of ferruginous sand and grey laminated clay with leaves. One of these leaf beds was exposed in the great cutting on the Reading and Basingstoke Railway, and was described by Prestwich in 1854.*

A leaf bed is reported to have been found on almost the same horizon by our members on June 3rd, 1876 ("Record of

* *Quart. Journ. Geol. Soc.*, vol. x, p. 88.

Excursions," p. 269) in the Waterloo brickfield on the western slope of Southern Hill, Reading. A leaf-bed, perhaps the same, was again exposed in the same brickfield in 1881 and I collected specimens from it.

It was soon afterwards concealed by rubbish, and I did not see it again for several years, not, I think, until 1901, when Mr. Shrubsole showed it to me in a small excavation in the same brickfield and not far from the spot where I had seen it twenty years before. On May 31st, 1902, the Association visited this excavation and many specimens of leaves were obtained.

A leaf-bed on about the same horizon as that at Reading has been found by Mr. Treacher in a brickfield at Knowl Hill between Twyford and Maidenhead (see Report of Excursion on July 6th, 1901, *Proc. Geol. Assoc.*, vol. xvii, p. 181), and a similar bed has also been recorded at Shaw Kiln, Newbury.*

In the Isle of Mull some beds with ferns, etc., are found among the basalts. They are of very early Eocene age.

In the opinion of the late Mr. C. J. Meyer the Wealden and the greater part of the Purbecks are not purely fluviatile or estuarine but of fluvio-lacustrine origin. In support of this view he pointed to the apparently quiet deposition of most of the strata, the absence of shingle, and of drift wood perforated by mollusca. In the Wealden, he adds, there is an absence of banks of broken shells.

You may remember the cliff section in the Wealden which we saw near Sandown at Easter, 1895, and I think you will agree that the beds of very thinly laminated shale full of Cyprids, with here and there layers of Paludina and Cyrena, did look very much like a lake deposit.

Large double shells of Unio are found in the Wealden, near Brook Point, in the Isle of Wight, and an account of the celebrated pine raft there is given in the report of our excursion of Easter, 1891. (*Proc. Geol. Assoc.*, vol. xii, pp. 163.)

I have collected double shells of Unio from the Upper Purbeck of Pevril Point, and I think that formation is as a whole of fresh-water origin.

Probably the Purbeck below the Cinder Bed is mainly fresh-water, thus the thin splitting shales full of Cyrena, which we saw in the Teffont Quarry last Easter, and which I think belonged to the Lower Purbeck, are probably a fresh-water deposit, and so is the flint-bed a little below the Cinder Bed in Durlston Bay.

The late Mr. Godwin Austen expressed an opinion that every mass of red sandstone would ultimately be referred to either a brackish or fresh-water origin (*Quarterly Journal of the Geological Society*, 1871, vol. xxvii, pp. 198), and probably the greater part of the Keuper and Bunter, a good deal of the Permian, and

* Whitaker's *Mem. Geol. Survey*, vol. iv, p. 285.

much of the Red Beds of the Coal Measures are of fresh-water or of lagoon origin.

I may remind you that Mr. Walcot Gibson considers the red colour of the upper part of the coal series of Staffordshire to be original. I was a good deal surprised at the thickness of those red beds which we saw at Whitsuntide, 1903, but I am quite prepared to believe them to be fresh-water deposits. The Bunter, as we see it, is certainly not of marine origin, though I think it quite possible that the pebbles may to some extent be derived from sea beaches of an older date.

The Bunter is rather variable as to the abundance or scarcity of pebbles. In the great pit which we saw in Trentham Park on June 2nd, 1903, the formation consisted of a vast mass of pebbles with well developed current-bedding. Here and there the strata were sandy, and occasionally, usually in the sandy parts, there were hard bands. The colour was on the whole red, but a light greenish tint prevailed in places.

As a contrast to this section I may mention the rock upon which Nottingham Castle stands, and which also belongs to the Bunter Pebble Bed Series. Pebbles are, however, not abundant, and the rock is a light coloured sand and sandstone, with only here and there a reddish patch. A few pebbles are scattered throughout and in places there is a fairly continuous layer of them, but they are small and not often more than an inch long.

I ought not to leave the fresh-water deposits without mentioning the Elgin Sandstone, for though we have not visited any sections in it, the formation seems to be more especially connected in our minds with one of my predecessors in this chair, Mr. E. T. Newton, who described the wonderful reptiles found in that formation. The sandstone in question is one of the common building stones of North Scotland, and is largely quarried about Cummingstown and Lossiemouth.

CLASS III.—ESTUARINE DEPOSITS.

This section is intended to include the deposits in an estuary or delta where fresh water mingles with salt water. The fauna is consequently a mixed one, and includes fluvio-marine and brackish water forms.

In some cases the deposits near the mouth of a river are of great thickness. An estuary is at times an area of depression, probably because drainage has a tendency to flow towards such an area. Thus the estuary of the Rhine has been an area of depression for a long time, and more than 1,000 feet of strata have been deposited in Holland since the beginning of the Pliocene, as is shown in Mr. Harmer's diagram (*Proc. Geol. Assoc.*, vol. xvii, p. 423, fig. 65). This area of depression has at times

extended so as to include the east of England, and we find the evidence of this in our Crag. The Forest Bed appears to have been deposited when the land at Cromer stood at about its present level, though the relative levels of the adjoining areas were probably very different, and a large part of what is now the North Sea may have been land.

It seems to be now decided that the stumps of trees which have been found in such numbers in the Forest Bed are not on the spot on which they grew, but have drifted down a river, probably the River Rhine. The shells are of both marine and fresh-water species, and the marine *Mya truncata* is found in the position of life, so we may safely call the Forest Bed an estuarine deposit.

On July 30th, 1902, we visited a section in the Chillesford Clay close to the church at Chillesford, and our Director, Mr. Harmer, expressed an opinion that the clay was an estuarine deposit; the fossils seem, however, to belong for the most part to marine species, and I feel inclined to think it better to place the Clay of Chillesford with the sea-coast deposits. It was, however, probably laid down near the mouth of a large river, the Rhine in fact, and perhaps the question is really where we are to say the estuary becomes sea? The Bembridge Marls are, as a whole, of estuarine origin and give a good example of a mixed fauna. Thus we find the fresh-water Limnæa and Paludina, and the marine Cytherea and oysters, whilst *Cyrena obovata* and *Cyrena semistriata*, which are estuarine shells, occur in great abundance. At St. Helens there is a marine band with Arca, Mya, Mytilus, and oysters. When we visited that locality, on April 16th, 1895, we collected from this marine band, and some of our party found specimens of the Arca.

The beds at Hengistbury Head, near Christchurch, Hants, belong to the Bracklesham Series, and are probably of estuarine origin. They contain large fragments of stems of trees and beds of ironstone. A dark clay near Boscombe, also of Bracklesham age, contains similar large blocks of wood, and many were lying on the shore when we visited the place at Easter, 1894. Our Director, Mr. Starkie Gardner, said he had found sharks' teeth in the same bed, and that the wood at that place and also at Hengistbury Head was bored by Teredo.

Honeycomb Chine at Boscombe has been excavated in white and grey sand evenly and horizontally stratified. One band is full of empty husks of the fruit Nipadites. The allied genus Nipa lives at the mouth of rivers in places liable to be flooded by sea or brackish water.

The Woolwich Beds are mainly of estuarine origin in the neighbourhood of London, but become more marine as we follow them to the east. At Erith the intermediate type prevails.

The finest section which I have seen in this series was in the

railway cutting near Croydon, which the Association visited on June 2nd, 1883. I think it was the first excursion of the Association which I attended. The mottled clay of the Reading Beds was well developed, and above it there were some beds mainly of estuarine character and with a total thickness of about ten feet. The fossils included Paludina, Planorbis, and Cyrena, and an oyster bed was closely connected with the strata in which the above fossils were found, so that there can be little doubt as to the estuarine character of the whole.

On June 15th, 1901, we saw another magnificent section through the Woolwich and Reading Beds at Orpington, on the South Eastern Railway. The details will be found in the report of the excursion by Mr. Holmes. (*Proc. Geol. Assoc.*, vol. xvii, p. 169.)

The mottled clays, which I believe to be of fresh-water origin, were replaced by a series of evenly stratified clayey beds containing an abundance of estuarine shells. In the upper part were some layers with oysters, and the lower part was pebbly.

At Upnor, which I visited with the Association on June 6th, 1891, there is another good section in the Woolwich and Reading Series. There was no mottled clay, but the beds were estuarine and possibly in part marine, for there is no doubt that we get nearer the mouth of the Woolwich and Reading river as we go eastwards. The section is given by Prestwich (*Quarterly Journal of the Geological Society*, vol. x, p. 107). I did not see his bed (c) at the top of the series, but (b), a finely laminated clay full of estuarine shells and with selenite, was well shown. Below it was a considerable thickness, perhaps 20 feet, of very white sand, with current-bedding in places and black pebbles at the bottom. The pebble bed was often a mere layer, but in one place it was six inches thick. The pebbles rested on the top of the Thanet Sand.

The Oolites are, on the whole, of marine origin, but estuarine beds are by no means absent. I may remind you of a very interesting day which we spent amongst the workings for iron-ore, near Wellingborough, in Northamptonshire (April 28th, 1894).

A photograph of the section at Finedon Hill is reproduced (*Proc. Geol. Assoc.*, vol. xiii, Pl. vii).

The series shown was as follows:

1. Limestones with a little clay containing Rhynchonella and other marine fossils.

2. Clayey beds with plant remains, vertical stems in places suggesting quite shallow water. (Upper Estuarine Bed.)

3. A series of limestones, with a little marl, &c., containing the estuarine Cyrena and also marine shells.

4. Sands without fossils, believed to represent the Lincolnshire Oolite.

5. Sands and clays with much carbonaceous matter, and again with vertical plant markings. (Lower Estuarine Bed.)
6. The Northampton Iron-ore Series.

In Yorkshire the estuarine phase is far more fully developed, and the greater part of the formations between the Cornbrash and the Lias are of estuarine origin. They are mainly sands with much current-bedding, and nodular beds with iron-ore occur in places. A few plants have been recorded from the Upper Estuarine Series, and in the Middle Series there is the well-known plant-bed at the northern end of Gristhorpe Bay; and in the Lower Series plant remains have also been found, and there are some thin beds of coal. Amongst these Yorkshire Estuarine Beds there are a few marine bands, mostly limestones.

The Coal Measures are, probably, to a considerable extent of estuarine origin. It appears now to be considered that the coal seams themselves are not the remains of forests in place of growth, but that the vegetable material of which they are formed has been, more or less, drifted, and that the seams should be classed with fresh-water or estuarine deposits—perhaps, most often, with the latter.

The limestone termed Spirorbis Limestone has usually been regarded as of fresh-water origin, but our Directors at Stoke-on-Trent, last Whitsuntide, remarked that Spirorbis is common in the marine part of the Coal Measures.

At Scremerston, on the Northumberland coast, the coal seams seemed to be very closely associated with limestones containing an abundance of corals, and, evidently, of marine origin.

In Scotland a large part of the Carboniferous System consists of the series which has been termed the Calciferous Sandstone, and it is, I think, in the main estuarine.

Dr. Traquair remarks ("Trans. Roy. Soc. Edinb., vol. xl, p. 688) that this series is, in the Edinburgh District, characterised by the rarity of marine beds, the principal limestone, that of Burdiehouse, being of estuarine origin, like the sandstones, shales, and ironstones which form the mass of the series.

The fossil trees of Craigleith Quarry have long been celebrated, they are not however I think in place of growth, but have probably drifted down a river. The trees are in sandstone and above the sandstone are the Wardie Shales which have furnished a rich fish fauna. Dr. Traquair says that the shales are estuarine though they contain some bands with Myalina, Schizodus, Lingula, etc., but with no hinged Brachiopods (Trans. Roy. Soc. Edinb., vol. xl, p. 690).

The oil shale which forms so important a feature in the

Calciferous Sandstone Series of the Edinburgh District is not unlike the Kimeridge Coal, but its origin is different, for the Kimeridge Coal is a marine formation deposited probably in deepish water, whereas the Edinburgh oil shale is probably of estuarine origin.

CLASS IV.—LAGOON DEPOSITS.

This division is intended to include deposits in sheets of water where salt has become concentrated by evaporation. Such deposits have been termed Caspian and are characterised by the presence of gypsum and salt. Animal remains are naturally scarce or absent. In the Paris Basin there are beds of Eocene age belonging to this class. I refer to the dolomitic beds in the Upper Calcaire Grossier and the gypsum beds of Montmartre.

In this country the Lower Purbeck is probably to a great extent a lagoon deposit. On April 4th, 1896, we saw some large concretionary masses of gypsum in the beds of that age in Durlston Bay, Swanage, and last Easter (1903) in a quarry near Ridge in the Vale of Wardour several of us found good examples of the hollows left by crystals of rock salt.

Rock salt and gypsum are found in the Keuper and that formation is probably for the most part a lagoon deposit.

The Bunter may also belong to the present class and the Permian was probably deposited in salt lakes, though the sea must have had access to the area during Magnesian Limestone times, for it contains Productus and other Brachiopods. At the same time fossils are not common in the Magnesian Limestone and I have searched in many of the large quarries in Nottinghamshire without finding a sign of a shell. Perhaps it was deposited in a sheet of water connected with the sea rather than in open sea.

During our excursions to Scotland in 1897 and 1903 we heard a great deal about the Ballagan Beds, and we saw a very good section in them in the cliffs near Burnmouth, July 30th, 1903. They consisted of sandstone showing current-bedding in places with some clays and shales and bands of cement stone.

Mr. Goodchild told us he had seen surfaces with sun-cracks, and also pseudomorphs after rock salt and deposits of gypsum suggesting shallow lagoons which dried up from time to time.

The Ballagan Beds are near the bottom of the Carboniferous Series and belong to the Calciferous Sandstone Group, which, as I have already mentioned, is largely estuarine.

The Old Red Sandstone is usually regarded as a lake or lagoon deposit, though it may be to some extent of terrestrial origin.

CLASS V.—COASTAL DEPOSITS.

i. THE SEA SHORE.—We have, amongst our geological formations, plenty of examples of deposits formed on or close to the sea shore. They consist of both coarse and fine material, sometimes arenaceous and sometimes calcareous. In the latter case the lime may be derived from adjoining cliffs or from shells, etc.

The Raised Beach of Gower, which we saw at Easter, 1902, is a good example of a detrital limestone deposit of marine origin. It consists chiefly of pebbles of the Carboniferous Limestone Rock of the coast. Shells more or less broken are common, and at one place in Port Eynon Bay we saw a considerable mass of shells and shell débris. Though the pebbles were mostly limestone, other rocks were not uncommon, and in some places I noticed a good many sandstone pebbles.

The Weybourn Crag is, I should say, a coastal deposit formed very near the shore. It was well exposed in the cliff at Weybourn at the time of our visits on April 3rd, 1893 and on August 4th, 1902. The bed was light coloured, sandy and chalky, with black subangular flints and also flint pebbles. There were several patches of shells, single valves of *Tellina balthica* abounded. And I noted many specimens of *Cardium edule*, also single valves, and *Littorina littorea*.

During the Easter excursion of 1893 we "had an opportunity" of visiting a fine section in the Bure Valley Beds, at Coltishall. They consisted of ferruginous gravel and current-bedded sand, with, in one place, a little laminated clay. Probably the whole was a coastal deposit formed near the shore, and, also probably, near the mouth of a large river.

The "Mammaliferous Crag" of Norwich has been classed with the estuarine deposits. Mr. Harmer, however, speaking of it as the Norwich Crag, told us that he considered it to be marine—though accumulated near the mouth of a river (*Proc. Geol. Assoc.*, vol. xvii, p. 446).

We spent a considerable time in the pit at Thorpe Kiln, near Norwich, on March 31st, 1893, and I collected many fossils and made a note of the section. The "Mammaliferous Stone Bed" is an accumulation of large flints, which have been but little water-worn, and a little clay. I found a few shells in the bed.

It rests on the chalk and forms a basement bed to the Norwich Crag at this place. It differs from the Suffolk Bone Bed, for I did not see any phosphatic nodules in it, though we were told a few occur. It is more like the bottom bed of the Reading Series, but the flints are more rolled. On the whole, I see no reason for separating the Stone Bed from the overlying sandy Norwich

Crag, and I should think it is of marine origin and accumulated near the shore.

The overlying sands are current-bedded and crowded with marine shells, the bivalves being mostly single valves, and many of the shells are waterworn. I should say, also, a coastal marine deposit near the shore.

The Red Crag is a coastal deposit formed, I think, close to the shore. It is very much current-bedded, the bivalves usually occur as single valves, and pebbles are common.

Prestwich found an actual shore-line in a pit near Wood Hall, Sutton. (See *Quart. Journ. Geol. Assoc.*, vol. xxvii (1871), p. 340.)

We spent some time in the pit on July 29th, 1902, but the section was not very clear, still we could see the Coralline Crag which formed the shore of the Red Crag Sea, and close by, in the same pit, we found the fossiliferous Red Crag itself. (See *Proc. Geol. Assoc.*, vol. xvii, p. 481.)

In the Bracklesham Beds of Whitecliff Bay there is one bed, No. 13, of Prestwich's section, which I believe to have been deposited close to the shore, for it is full of broken and water-worn shells as well as pebbles. (See *Proc. Geol. Assoc.*, vol. xiv., p. 100.)

The Basement Bed of the London Clay is a marine coastal deposit succeeding to the fresh-water mottled clays of the Reading Beds, and preceding the London Clay, which belongs to the next or Bathial Class of Deposits.

At Reading, where we have often seen the Basement Bed, it consists of sand and clayey sand with a few pebbles, and layers of *Ditrupa plana*, and marine shells. Pectunculus, Cytherea, and Protocardium are the commonest bivalves, and they usually, but not always, occur as single valves.

We saw a good example of a pebbly coast deposit of Eocene age in the cuttings on the South Eastern Railway at Sundridge Park, Chiselhurst. The Woolwich Beds at that place are, as I have said, of freshwater or estuarine origin, but in Oldhaven times the sea advanced over the area south and south-east of London, and at Sundridge Park had cut into the Woolwich Beds, so that at the Chiselhurst end of the section the Oldhaven Beds rest on the bottom bed of the Woolwich Series. (See Whitaker, London, vol. i, p. 227.)

The Oldhaven Beds consisted of sand and pebbles, the whole much current-bedded. In places there were numerous irregular layers of calcareous concretions and in most cases these were full of shells. Towards the eastern end of the section masses of oysters occurred and also collections of Cyrena. In other parts of the section the most common fossil was the marine shell Pectunculus, usually single valves, piled together in the most irregular manner one inside another.

ii. OYSTER BEDS.—Beds of oysters are found at many geological horizons. There is a good example in the marine part of the Middle Headon of Colwell Bay. (See Report of the Excursion on April 15th, 1895, *Proc. Geol. Assoc.*, vol. xiv, p. 110.) I have already mentioned oyster beds in the Oldhaven and amongst the shell beds of the Woolwich Series. I noted examples in the latter formation in the railway cuttings at Park Hill, Croydon, and at Orpington, and Mr. Whitaker mentions others at Charlton, etc. (See "Geology of London," vol. i, pp. 147–8, etc.)

There is frequently a layer of *Ostrea bellovacina* in the bottom-bed of the Reading Series. At Reading it is a very marked feature and the oysters usually have the valves united. In one place there are two layers of oysters; they lie in a green sand, with a few pebbles, and sometimes there are also sharks' teeth and a few marine shells. The green sand rests on the Chalk, and at the bottom there are numerous green-coated flints which have not been rolled or waterworn.

I almost think that the layers of *Exogyra conica* in the Upper Greensand at Punfield Cove, near Swanage, may be included with the oyster beds. Associated with the Exogyra I have found many bivalves with closed valves which probably lived on the spot. I may mention *Cucullæa glabra*, *Pecten orbicularis*, *Pecten asper*, and *Spondylus striatus*.

The Cinder Bed of the Middle Purbeck is an oyster bed. We saw it in the quarry near Teffont Church last Easter (1903). It was about a foot thick and consisted of a grey limestone full of shells of *Ostrea distorta*. At Lady Down, too, the Cinder Bed was well marked in the quarry in which we sheltered (?) and lunched during a snowstorm. At Swanage, 42 miles south of Teffont, the Cinder Bed is well developed, and in Durlston Bay it attains a thickness of between 8 and 9 feet. It is there a compact mass of shells of the oyster, amongst which are a few specimens of Cardium, Perna, and Trigonia; together with the spines and plates of *Hemicidaris purbeckensis*.

The Cinder Bed is also found at Upway, north of Weymouth, 24 miles west of Durlston Bay and 47 miles south-west of Teffont.

The Perna Bed near the top of the Portlandian may be classed with the oyster beds. At Tilly Whim, near Swanage, it is about 12 feet thick and is a mass of shells of *Perna bouchardi*. On our excursion to Swanage, at Easter, 1896, we saw the bed in several quarries along the coast from Tilly Whim to St. Albans Head.

Mr. H. B. Woodward mentions a bank almost entirely composed of *Ostrea acuminata* in the Fuller's Earth Series on the borders of the Fleet south of Langton Herring, near Weymouth ("Geology of England and Wales," 2nd edit., p. 296).

I feel inclined to place the Scarborough Limestone amongst the oyster beds. The formation is closely connected with the thick estuarine series, above and below it, and Mr. Hudleston mentions ripple-marked slabs in the limestone at Hundale Point (*Proc. Geol. Assoc.*, vol. iii, p. 313); it was consequently formed near the shore, and in places there are layers of *Avicula braamburiensis* and other layers of *Gervillia acuta.*

I do not suggest that all the above which I have placed together as oyster beds were formed in shallow water. I fancy that the oyster and its allies like a good current, and that, given the current, an oyster bed may be formed at a considerable depth.

iii. Shallow Water Near the Sea Shore.—We have a number of current-bedded, sandy deposits which contain marine fossils, the valves of the bivalves being sometimes single and sometimes united. I may mention the Coralline Crag, the Barton and Bracklesham, the Lower Greensand, the Forest Marble, Stonesfield Slate, and Millstone Grit, as all coming to some extent within the above terms, and to that extent, I think, they were probably formed fairly near the shore and should be classed with the coastal deposits.

iv. Deep Water Near the Sea Shore.—There are other geological formations which, though they contain fossils of much the same genera, and even species, as the deposits mentioned above, differ from them in being seldom current-bedded, and have probably been deposited in still and rather deep water, though not far from the shore. These formations are formed of detrital matter, whether they be arenaceous or calcareous, the fossils are all marine, are not crushed, and the valves of the bivalves are usually united and closed.

The Barton or Upper Bagshot Beds of the London Basin are a good example. We saw a section in them at Tunnel Hill, near Aldershot, on June 6th, 1903. They consist of yellow sand, there is no current-bedding, in fact, very little sign of bedding at all. The fossils occur as casts only, but the genera and even species can often be identified.

The following bivalves are fairly common and have the valves united: Cardita, Corbula, Crassatella, Cytherea, Lucina, Nucula, Pecten, Pectunculus, Protocardium, Strigilla, Tellina, and the little *Ostrea plicata*. These sands were probably deposited in a wide bay or open sea not far from land.

The Thanet Sands are another example of this class. When we were at Upnor on June 6th, 1891, I noticed that they were yellow and white sands in thick massive beds, and that they differed markedly from the current-bedded sands of the Woolwich Series above them in the same section.

The Portland Series belongs mainly to this class of deposit. At Wockley, in the Vale of Wardour, we saw a good section in

its upper part and its junction with the overlying Purbecks. Near the top of the Portlands there was a bed full of fossils, amongst them I noticed a great number of *Pecten lamellosus*, which appeared to have lived on the spot, for the shells were not waterworn and the valves were united and closed.

Near Swanage, too, the shells of Cardium, Cyprina, and Pleuromya, in the Portlands, are generally in good condition, with united and closed valves. The big Portlandian Ammonites appear to have lain for some time as dead shells on the sea bottom, for there are signs that oysters lived inside them before they became filled with the calcareous mud.

The Kellaways Rock is a phase of the Oxfordian which bears considerable resemblance to the Upper Bagshot and Thanet Beds. On our Whitsuntide excursion of 1896 we saw a section in the rock at Kellaways itself, and I collected many specimens of *Myacites recurvus* as well as a number of Rhynchonella and Waldheimia with the valves united and closed. In the same formation in Yorkshire I have found specimens of a large Pholadomya, of Gervilleia, and of other bivalves in a similar condition.

The Inferior Oolite is probably to a large extent composed of the waste from coral reefs, and both it and the Midford Sands probably belong to the class of deposit with which I am now dealing.

CLASS VI.—BATHIAL DEPOSITS.

I now come to a series of clays, shales, marls, &c., probably deposited in deeper waters than any in the last class, and to some extent corresponding to the fourth bathymetric zone of the zoologists.

Brachiopods are usually abundant, and there are great numbers of the shells of animals, such as Ammonites, which live near the surface of the sea.

In many cases deposition appears to have been fairly rapid, for beds of crushed Ammonites, &c., are a common feature in this class of deposit. These shells were probably buried before the decay of the animal had allowed the sediment to fill the interior of the shell, and the shell consequently was crushed by subsequent pressure. In many cases the outer chambers of the larger Ammonites had become full of sediment and have been preserved from crushing, whilst the inner chambers of the same shell have been crushed.

In the Middle Headon, Barton, and Bracklesham formations we find clayey beds full of marine fossils with many double bivalve shells, and probably these should be to some extent included in the bathial class, or, perhaps, we should consider them as intermediate between the coastal and the bathial

deposits. They were most probably laid down in the sea in deepish water and at no great distance from the mouth of a large river.

The London Clay may well have been deposited in a tract of sea, such as the German ocean, fifty or a hundred miles off Harwich. The fossils are for the most part marine, and the bivalves are generally double. The genera are not as a rule deep-water forms, and at Sheppey and Harwich numerous remains of turtles and fruits and seeds show that the mouth of a large river was at no great distance.

The Chloritic Marl, Upper Greensand and Gault may, I think, be classed, to a large extent, with the bathial deposits, though part of the Upper Greensand should, I think, go into the coastal class.

The sea extended over East Yorkshire during Purbeck and Wealden times, when so much of our island was land, and in consequence we get in Yorkshire a continuous series of clays crowded with Ammonites and other marine shells. It is known as the Speeton Series, and is a bathial deposit.

The Kimeridge Clay also belongs to the present class and was deposited during a time of extensive submergence, when the sea stretched from Normandy to Yorkshire; though, probably, there was land in our south-eastern counties and also in Cornwall and Wales.

The Ampthill Clay, the Oxford Clay, and the greater part of the Lias belong to the bathial class, and, possibly, I should add the Fuller's Earth.

In the Carboniferous there are some fairly thick beds of shale with an abundance of Cephalopods and Brachiopods, which I am inclined to class with the above clays.

You may remember the gannister quarry in the Congleton District, which we visited on June 8th last (1903). I was much struck by the abundance of Brachiopods in the shales. One bed about five feet thick was a mass of the shells of *Orthis resupinata*. The beds belong to the Pendleside Series.

In Gower, on March 31st, 1902, we collected Gonatites from dark shales belonging to the Gower Series, probably of Millstone Grit age. The shells were very numerous and were crushed, and reminded me of the shales with crushed Ammonites which we have seen in the Kimeridge Clay.

I think we should probably class the Graptolite Shales of the Silurian and Ordovician with the bathial deposits.

CLASS VII.—PELAGIC DEPOSITS.

These deposits were accumulated too far from the shore for them to contain more than a trace of detrital sediment, and they

are consequently formed of organic material and are represented at the present day by the Ooze of the Atlantic Ocean.

The Chalk for the most part belongs to this class, as does the greater part of the Carboniferous Limestone, and some of the Silurian, Ordovician, and Cambrian Limestones.

We have seen something of many of these formations in recent years, but I do not propose to deal with them this evening.

CLASS VIII.—CORAL REEFS.

Probably many of our Jurassic strata are composed of the débris of coral reefs, but it is not easy to say to what extent we have the coral reefs themselves.

Speaking of the Coral Rag, Lyell remarked ("Elements of Geology," 6th edit., p. 395) that it consists in part of continuous beds of petrified corals, for the most part retaining the position in which they grew at the bottom of the sea. In their forms they more frequently resemble the reef-building poliparia of the Pacific than do the corals of any other member of the Oolite.

The celebrated quarries near Marcham, in Berkshire, were visited by the Association on April 19th, 1892, and they have been described by Messrs. Blake and Hudleston (*Quart. Journ. Geol. Soc.*, vol. xxxiii, pp. 305-308). In their account of the quarry at Bradley Farm, those authors say, "we have at the top about six feet of magnificent Rag, the massive portions growing in lenticular masses with bases not horizontal, and the intermediate spaces filled to a large extent with *Thecosmiliæ*. The reef-corals here are in a more perfect state of preservation than in any locality we know of, and leave little to be desired." On the other hand, Professor Blake considers that the masses of corals which are found in the Corallian at Hackness, in Yorkshire, are not in their place of growth, but are fragments torn from a reef elsewhere (*Proc. Geol. Assoc.*, vol. xii, p. 135).

On August 3rd last we saw good coast and quarry sections in the rocks of the Scremerston Coal Series, which Mr. Goodchild told us was on the same geological horizon as part of the Mountain Limestone of North-west Yorkshire, and also contemporaneous with the oil shale series of the Edinburgh District. Now the former of these formations probably belongs to the Pelagic and the latter to the Estuarine class, so that we may be in some doubt as to the class in which we should place the various beds of the Scremerston Coal Series. The limestones are crowded with corals, but Mr. Goodchild said they were not reef-building forms and he did not consider that there was a coral reef *in situ*.

CLASS IX.—ABYSSAL DEPOSITS.

It is probable that some of our Silurian, Ordovician, and Cambrian rocks were deposited in the depths of an ocean, and may be classed as Abyssal Deposits.

This matter was discussed to some extent during our Long Excursion last year. Our Director, Mr. Goodchild, said that the radiolarian chert of the Ordovician of the Tweed area agrees in all essential respects with the modern deep-sea radiolarian ooze, and he seemed to favour the idea that it had been deposited under similar conditions as to depth.

Mr. Horne has expressed a similar opinion with regard to some of the rocks of the Clyde basin. He says, "One prominent rock-group preserves, with rare exceptions, its uniform lithological character throughout the uplands. It consists of cherts and mudstones partly of Upper Arenig and partly of Lower Llandeilo age, which, where not deformed or altered by intrusive igneous masses, are richly charged with Radiolaria. The mudstones contain hingeless Brachiopods and other organisms. The cherts, which have been formed from a true radiolarian ooze, and the mudstones imply an oceanic phase of sedimentation." ("Brit. Assoc. Glasgow Handbook," 1901, p. 403.)

I have not this evening time to enter more fully into these deep-sea deposits, and I can only thank you for the kind attention with which you have listened to my remarks, and now that I have completed my term of office as your President I desire to express my sincere appreciation of the honour you did me in electing me, and of the great kindness I have received from all the members of the Association during the past two years. I am more especially indebted to my fellow-officers, and I can assure them that I fully appreciate the large amount of time and work which they have given to our Association.

My successor needs no introduction to you. Dr. Smith Woodward, the Keeper of the Department of Geology at the British Museum, is not only well known to all of us here, but has a wide reputation as a geologist, both at home and abroad. He has always taken a keen interest in the Association, and I feel it a great honour to be succeeded by him as your President.

AN INDEX

TO

ROWE AND SHERBORN'S "ZONES OF THE WHITE CHALK OF THE ENGLISH COAST."

(" PROC. GEOL. ASSOC.," XVI (6), 1900; XVII (1), 1901; XVIII (1), 1903; and XVIII (4), 1904.)

By C. DAVIES SHERBORN.

IN these contributions to our knowledge of the White Chalk many observations are scattered throughout the text, which it seems desirable to bring together by means of an index.

The papers are referred to as I (Kent and Sussex); II (Dorset); III (Devon); and IV (Yorkshire).

EXCURSION TO THE NEW RAILWAY AT HADDENHAM (BUCKS).

MARCH 5TH, 1904.

Director: A. MORLEY DAVIES, B.SC., F.G.S.

Excursion Secretary: HAROLD WALKER, A.R.C.SC., F.G.S.

(*Report by* THE DIRECTOR.)

A PARTY of eleven gathered in a cold east wind at the bridge which carries the road from Aylesbury to Thame over the new line, close to the milestone indicating seven miles from Aylesbury. Descending into the cutting, the sides of which had been sloped except near the bridge, the following general section was seen:

		Feet	inches.
	Soil	1	6
UPPER PORTLAND.	7. Buff sands, with some rubbly limestone in places	2	6
	6. Very glauconitic sand	1	0
	5. Buff sand	2	4
	4. Wet sand with limestone nodules	1	2
	3. Pebble-bed	0	9
LOWER PORTLAND.	2. Buff dry sands	6	6
	1. Black wet sands, more clayey towards the base, not bottomed	4	3+
		20	0+

These measurements are approximate, being calculated from measurements on the sloped surface. The black wet sands at the base are probably over ten feet thick, no lower strata having been met with in this cutting.

The Director explained that these beds belonged to the Portland series, and that in his opinion the pebble-bed was identical with the one which in the Aylesbury district immediately followed the Hartwell Clay, and was taken by Mr. H. B. Woodward as a convenient base for the upper division of the Portland series. The view that the pebble-bed now before them (and the similar one seen at Scotsgrove Hill, Long Crendon, and other places farther west) was identical with the Aylesbury one, involved the belief that this pebble-bed maintained its continuity while the beds above and below it changed their character. Some justification for that belief would be seen as they followed the cutting farther to the south-east.

A close examination of the beds was now made, and it was found that on the south side of the bridge, where they were more accessible, there was a greater development of limestone in No. 3, and in it many worm-tubes, and some casts of *Protocardia* (? *dissimilis*) and Ammonites of the *biplex* type; a few pebbles

similar to those of the pebble-bed were also noted. In the pebble-bed proper, the pebbles were seen to be mostly "lydite," but among them were a few fragments of phosphatic casts of Ammonites of the *biplex* type* such as are recorded from the pebble-bed at Hartwell, and were also found at Dadbrook Hill on the Association's visit in 1899. These derived fossils of *quasi* contemporaneous age seem to show that the formation of the pebble-bed was preceded by an interval during which no deposition took place, and there was even some erosion of the sea-floor.

Following the cutting south-eastwards, the party noticed that the strata had a gentle dip in that direction. At the same time some changes in their character occurred, and by the time the pebble-bed came to be accessible from the bottom of the cutting it was found that the pebbles were embedded in a bluish glauconitic limestone. Above this blue limestone came the rubbly white limestone, still containing a few pebbles also. From these beds a number of fossils were obtained, afterwards kindly identified by Mr. E. T. Newton as follows:—

Trigonia incurva, Benett.	*Exogyra nana*.
Mytilus unguiculatus, Phil.	*Exogyra* sp.
Pecten lamellosus, Sow.	*Pleuromya tellina*.
Lima rustica, Sow.	*Serpula* sp.
Lima sp.	

There were also found several Ammonites of the type commonly known as "*A. biplex*," which have not been more precisely identified.

The ascending sequence of strata was now hidden for a while by the unconformable superposition of a gravel, consisting of small fragments of Portland limestone and ironstone, with some pebbles like those of the pebble-bed (including an ammonite-cast), but no flint. As exposed the previous summer the fluviatile character of this gravel had been more clearly shown, lenticular patches of sand being seen in it, and a marly deposit underlying it. Neither of these could be seen now, but any suspicion of its possible Purbeck or Lower Cretaceous age was dispelled by the discovery in it of small rolled Belemnites (identified by Mr. Crick subsequently as *B. minimus*, Lister, of the Gault).

Thus the gravel is plainly newer than the Gault, and indeed of later date than the recession of the Chalk escarpment from this area; while the absence of flint precludes the possibility of its deposition by a stream flowing from the Chalk escarpment north-westwards to the Thame. The only direction from

* These have been since submitted to Mr. G. C. Crick, who kindly states that they seem to belong to a section of the genus *Holcostephanus*, that their age is uncertain, but that they are suggestive of Kimeridgian forms.

which the gravel could be derived seems to be the north-west, where there are outliers of each of the formations from which its materials are derived (Gault, "Lower Greensand," and Portland), and no Chalk. But if it were derived from the north-west, the Thame could not then have been in existence. Now it is tempting to notice that opposite this point a tributary enters the Thame, and indeed its existence accounts for the railway taking this particular course. But if the Thame were non-existent, and that tributary continued its course at the level of this gravel, about 260 feet above O.D., it would be nearly 200 feet too low to make its way across the Risborough Gap in the Chilterns. In view of the difficulty of the problem presented, some regret was felt at the absence of any gravel specialist from the party.

The gravel presently ended off against a bank of Upper Portland limestone, and now the road from Thame to Haddenham was reached. Beyond the road for some distance the cutting had not yet been begun, but after a walk of three or four hundred yards the working face was reached. Here the typical "Lower Greensand" of the district was seen—reddish sands with ironstone. A hunt was made for fossils, but without result. It is to be hoped that as the cutting advances more light may be thrown on these beds, but little could be made out on this occasion.

Farther on, Purbeck marl was seen with nodules of chert (like those found at a pit between Kingsey and Towersey); and some thin clayey beds with Ostracods, which gave a strongly bituminous smell on being hammered. No good fossils were found in these. In the underlying Upper Portland limestones numerous casts of *Natica*, *Pleurotomaria*, *Trigonia gibbosa*, *Protocardia dissimilis* and "gigantic" Ammonites were found, but no rarities being discovered the members soon tired of collecting and adjourned for tea in the village.

During part of the afternoon Mr. W. H. Haydon, the resident engineer of the railway, accompanied the party and gave some account of the work in progress.

REFERENCES.

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Ordnance Map, new 1-inch sheet, 237. Price 1s.
1899. DAVIES, A. M.—"Contributions to the Geology of the Thame Valley." *Proc. Geol. Assoc.*, vol. xvi, p. 15.
——————————"Excursion to the Thame District. *Ibid.*, p. 157.
For other references, see these papers.

EXCURSION TO THE CROYDON BOURNE.

MARCH 12TH, 1904.

Director: W. WHITAKER.

(*Report by* THE DIRECTOR.)

THE party (of about eighty) went to Woldingham Station and thence walked northward, more than half a mile, to Bughall Farm, the highest spot at which the bourne had broken out.

Here a halt was made and remarks were made on the general characters of bourne outflows, with especial reference to the present case of these intermittent springs.

The inadequacy of the old idea of a syphon to explain them was noticed, it being hardly conceivable that such a thing could exist in a rock like the Chalk, whilst it was simply impossible to shift any such wildly improbable syphon up and down a valley, over a course of some miles, to suit the varying places of outburst.

Under ordinary circumstances there is no stream in this valley, it being one of the dry Chalk valleys, but after a very wet season, or a succession of moderately wet seasons, the level of the underground water in the Chalk rises, especially under the higher grounds, and after a time to so great an extent that it reaches the level of the valley-bottom, when of course the water begins to come out to the surface. The earliest rising-point of the stream is a little below the "Rose and Crown"; but a short way lower down the valley the water sinks in again to some extent, and the stream decreases. The rising-point gradually gets farther and farther up the valley as the underground water-level rises, until the greatest flow occurs, and then, as the flow decreases, the rise of the stream gets lower again with the decrease of the underground water-level, until at last the outflow ceases, and the valley returns to its usual dry state.

It was pointed out how, by fairly continuous measurements of the water-level in wells in and near the valley, the gradual rise of the underground water-level was recorded, and how, by this means, Mr. Baldwin Latham was able to predict when the outflow of this particular bourne was to be expected. As his predictions invariably came true, he would, in the good old times, have been duly burnt as a magician; now he was only regarded as a champion recorder of water-levels, a harmless and even beneficent character.

The walk was then continued along the bottom of the valley westward for rather more than another half mile, the great increase in the flow of the stream being noticed down to Wapses Lodge, where a slight accession came in from the branch of the valley to the south. Here, then, were large

ponds, the stream broadening and spreading out beyond its proper channel.

The walk was continued northward down the valley, here a populated tract, and the flooding of various gardens, etc., was noticed.

After passing Whiteleaf the party came to the chief flooded area, by the gasworks, where there was a small lake, in which a new gasholder was apparently taking a bath.

Below the gasworks the road was left, and tracks were made along the fields, in order to give members pedal demonstration of the flooding, and to show them the fullest part of the stream.

At Garston House, half a mile north-west, the road was again taken, and the precautions taken at the Kenley pumping station of the East Surrey Water Company to save their customers from an addition of bourne-water to their supply were noticed.

The course of the bourne is then chiefly in an artificial channel, partly a closed culvert (through Kenley).

About a quarter of a mile below Kenley Station a curious thing was seen. Here, close to the artificial channel of the bourne, was a small pit, in loamy soil and gravel to the depth of about seven feet below the water, and yet it was dry. A like thing, but to a less extent, was seen a little farther down, and it seemed as if the stream had fairly puddled its channel.

The course of the stream was seen, from the road, down to Purley, where, at the new works of the East Surrey Water Company, an old gravel pit was seen to be flooded, and there was a good deal of flooding by the houses just below. There has also been flooding a short way up the other branch of the valley, southward, along the Brighton Road, and at Stoat's Nest, still higher up.

From Purley to Croydon the bourne is largely in a culvert. In old times the lower part of Croydon used to suffer much from the bourne.

The last outflow was in 1897, when it reached up to Wapses Lodge in March and April. The greatest flow recorded this time was about twelve million gallons a day (February 16th), or more than enough for the supply of a large town like Croydon for three days.

NOTE.—Mr. Baldwin Latham is going to read a paper on the Bourne to the Croydon Natural History Society, and when this is printed we shall have a detailed account of great value.*

* Read on May 17th, 1904, and printed as a pamphlet entitled, "Croydon Bourne Flows."—[ED.]

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY).

MARCH 19TH, 1904.

Director: E. A. NEWELL ARBER, M.A., F.L.S.

Excursion Secretary: HAROLD WALKER, A.R.C.Sc., F.G.S.

(*Report by* THE DIRECTOR.)

MEMBERS assembled at 2.30 p.m. by the Owen Statue in the Central Hall, and proceeded to the Geological Galleries, where they were met by the director, who demonstrated the succession of Palæozoic Floras, considered especially with regard to their composition and distribution. He pointed out that the earliest remains which were generally admitted to be of vegetable origin, occur in the Silurian rocks of Britain and North America. Specimens of *Nematophycus* and *Pachytheca*, two of the best known of Silurian Algæ, were shown. Emphasis was laid on the fact that several plant-bearing beds, which had been described as being of Silurian age, were really of later date. As an illustration, specimens from the St. John's beds of New Brunswick, regarded by Dawson and others as Silurian, were shown, and it was pointed out that the genera and many of the species occurring in these beds were identical with those of the British Coal Measures.

The identity of the Upper Devonian and Lower Carboniferous floras, and the chief classes of plants then in existence, were next demonstrated. Attention was also called to the world-wide and uniform distribution of the plant life of this period.

Passing to Upper Carboniferous and Permian times, it was shown that two great botanical provinces existed, whose floras were largely but not entirely distinct. That of the Northern Hemisphere, including Europe, Northern Asia and North America, consisted of such genera as *Calamites*, *Lepidodendron*, *Sigillaria*, with numerous Ferns, and members of two very interesting extinct groups, the *Cycadofilices* and *Cordaitales*. British examples of many of these genera were pointed out among those exhibited in a large case, recently rearranged by the lecturer.

The flora of the Southern Permo-Carboniferous Continent, embracing India, Australasia, South Africa and South America, was especially characterised by an abundance of a fern-like plant known as *Glossopteris*, and is often spoken of as the Glossopteris Flora.

It was pointed out that although the same classes of plants are represented in both the Northern and Southern Permo-Carboniferous floras, they are, with the exception of the Lycopods and Sphenophyllums, generically extinct. Attention

was called to a case, recently arranged by the lecturer, in which the various members of the Glossopteris Flora are exhibited side by side. Brief explanatory labels indicating the chief characters of the specimens, and maps showing the distribution of the genera, are included with the species exhibited.

EXCURSION TO THE VALE OF EVESHAM AND THE NORTH COTTESWOLDS.

April 1st—5th (Easter), 1904.

Directors: Dr. C. Callaway, M.A., F.G.S., and L. Richardson, F.G.S.

Excursion Secretary: Dr. C. G. Cullis, F.G.S.

(*Report by* L. Richardson.)

The official party left Paddington (G.W.R.) at 4.45 p.m. on Thursday, March 31st, and on arrival at Evesham proceeded to the Crown Hotel, where it was joined by many members who had travelled by other trains or from different parts of the country.

Friday, April 1st.—The party drove from Evesham to Broadway, a most picturesque village pleasantly situated at the foot of Broadway Hill. Leaving the brakes the members walked to the top of the hill, passing *en route* an exposure of the Marlstone or "rock-bed" of the Middle Lias. Mr. Richardson stated that there were several exposures of this rock along the escarpment, but that few were of interest to the palæontologist. The members, however, would have the opportunity on the morrow of investigating one of the most fossiliferous exposures of the rock in this area. The position of the sandy clays below the Marlstone was then indicated, at the base of which it was stated springs frequently burst out, and the ground was always damp. Gorse also indicates the presence of the arenaceous shales, and indeed these bushes are often of service to the geologist, as they usually indicate the presence of a sandy deposit. Having reached the summit the members visited the large freestone quarry on the south side of the main road near the Fish Inn. Here the rock quarried is the lower portion of the Lower Freestone, and the upper part of the Pea-grit-equivalent. The latter deposit is less massive than at Temple Guiting, and the blocks of stone are frequently traversed by peculiar ramifying "borings." The *Clypeus*- and Upper *Trigonia*-grits have been let down by faulting in the centre of the section presented in the south face of the quarry, and from this débris were collected *Clypeus Ploti*, *Terebratula globata* and varieties, *Rhynchonella* aff. *hampenensis*, *Lima gibbosa*, *Pecten* spp., *Pholadomya Heraulti*, *Myacites* spp., *Trigonia costata*, *Avicula digitata*, and several other fossils. A blackish and extremely tough clayey deposit was observed lining the upper portion of the western edge of the fissure immediately above the Lower Freestone. Although its

exact stratigraphical position cannot be determined it was most probably laid down during the Lemera *concavi*, and has been displaced by the faulting which has affected the grits.

The next section visited showed the Notgrove Freestone and Gryphite-grit. A number of specimens of the *Pecten personatus*-type were obtained from the former subdivision, while from the latter were procured *Gervillia* sp., *Gryphæa sublobata*, and *Belemnites* (*Pachyteuthis*) *gingensis*. Near the top of the grit a number of well-rolled pebbles were noticed embedded in a shaly parting about three inches thick; an interesting fact, because it indicates another pene-contemporaneous erosion.

Arrived at the Monument, Mr. Richardson pointed out the geography of the scene before the members, and observed that they were standing upon the divide between the Severn and Thames systems, for whereas the rain falling on the escarpment augmented the supply of water carried off by the tributaries of the Severn, that falling in the hollow immediately to the east found its way into the Thames. The considerable growth of gorse-bushes in this hollow on the east attracted attention, and it was pointed out that they indicated the presence of an arenaceous deposit—the Harford Sands.

From the Monument the members directed their steps southwards, and on the Common above Snowshill saw a quarry in the Notgrove Freestone with the characteristic little Pecten. Close at hand was a section in the Harford Sands. A massive bed of sandstone was seen to overlie an accumulation of whitish sand with calcareous masses, and visible to a depth of 3 feet 6 inches. From the rock-bed were obtained *Nerinæa*, *Serpula* aff. *socialis*, *Modiola*, *Ostrea*, *Astarte* and *Terebratula*. Evidence of the Snowshill Clay was noticed in a small excavation also on the Common.

After lunch in Snowshill, the party visited a quarry in the hill-side to the south of the village. It showed the following section:

QUARRY NEAR SNOWSHILL.
(Between the Old Campden Road and the village).

		ft.	ins.
Clypeus-GRIT.	1. Rubbly rock with bodies somewhat resembling pisolite-spherules; crowded with *Myacites* spp., *Pecten*, and *Lima gibbosa* .		
	2. Rubbly whitish limestone with few fossils		
UPPER *Trigonia*-GRIT.	3. Somewhat massive bed slightly ironshot. *Rhynchonella* aff. *subtetrahedra*, *Rhyn. hampenensis*, *Terebratula globata*, *Modiola*, and *Pecten*. The upper surface of this bed is bored in places and covered with *Ostreæ* as at Cowley Wood, near Cheltenham . .	2	5
	4. Rubbly marly deposit, distinctly ironshot, *Terebratula globata*	0	8
NOTGROVE FREESTONE.	5. Freestone, hard, with whitish oolite-granules. Top-bed bored and has oysters adhering	25	0

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J. ALLEN HOWE, B.Sc., F.G.S.

(Authors alone are responsible for the statements in their respective Papers.)

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(*Continued on page 3 of the Cover.*)

An exposure of Oolite Marl in the east bank of a field-road thirteen-sixteenths of a mile east-south-east of Snowshill did not appear at a distance to be very promising, but upon closer inspection the rock exposed proved extremely fossiliferous, the specimens found including, *Pseudoglossothyris curvifrons* (abundant), *Terebratula fimbria* (very rare), *Rhynchonella Lycetti* (fairly abundant), *Rhyn.* of a *subangulata*-type (abundant), *Rhyn. subobsoleta* (somewhat rare), *Zeilleria Leckenbyi*, and the variety *Witchelli*, *Ctenostreon pectiniforme*, *Modiola*, *Lucina Wrighti*, *Alectryonia* cf. *flabelloides*, *Pholadomya*, *Cucullæa*, *Pleurotomaria*, etc.*

On the return walk the Seven Wells were visited, and the water was seen running off the Snowshill Clay. After tea in Broadway a few of the members visited the cutting at Broadway Station, on the Honeybourne and Cheltenham line, which is in the course of construction. They were rewarded by finding *Microceras subplanicosta*, *Gryphæa arcuata*, and another species, *Arca*, *Dentalium* cf. *elongatum*, *Belemnites*, and several species of gasteropods, the beds whence these specimens were procured being of the hemera *armati*. The party then drove back to Evesham.

April 2nd.

Saturday was devoted to an examination of the country around Chipping Campden and Blockley. The members left Evesham by the 10.46 a.m. train, and on arrival at Campden at once started on their walk. The first halt for geological purposes was made in a cutting through which the lane to Dover's Hill passes, and in which the marlstone was admirably exposed. The rock cut through has a thickness of at least 10 feet, and from it were obtained, *Paltopleuroceras* (probably *pseudocostatum*), *Rhynchonella amalthei*, *Rhynchonella* cf. *northamptonensis*, *Rhynchonella* sp., *Terebratula punctata*, *Pseudopecten æquivalvis*, *Pecten* aff. *demissus*, *Oxytoma* (*Avicula*) *inæquivalvis*, *Protocardium truncatum*, *Gryphæa cymbium?* (young), *Modiola*, *Pleuromya* aff. *costata*, *Pentacrinus*, *Ditrupa* cf. *quinquesulcata*, *Dentalium elongatum*, etc.

Ascending Westington Hill the members had a fine view over the town of Campden, and Mr. Richardson pointed out Meon Hill, the most northern point of the Cotteswold Range; and Dover's Hill, upon the summit of which in the past were celebrated "Mr. Rob. Dover's Olimpick Games."†

After lunch in the Westington Hill Quarry, the members proceeded to examine the section. Mr. Richardson observed that most of the buildings in Chipping Campden had been constructed

* On a previous visit the Director obtained in addition to the above, *Pseudoglossothyris* (*Terebratula*) *simplex* (dwarf form), and *Ter. submaxillata*.

† See *Proc. Cotteswold Nat. F.C.*, vol. xiv, part iii (1903), p. 212.

of stone quarried here by means of mines, and drew attention to the fact that whereas here the best stone occurred some 8 or 9 feet below the Oolite Marl, at the Jackdaw Quarry on Stanway

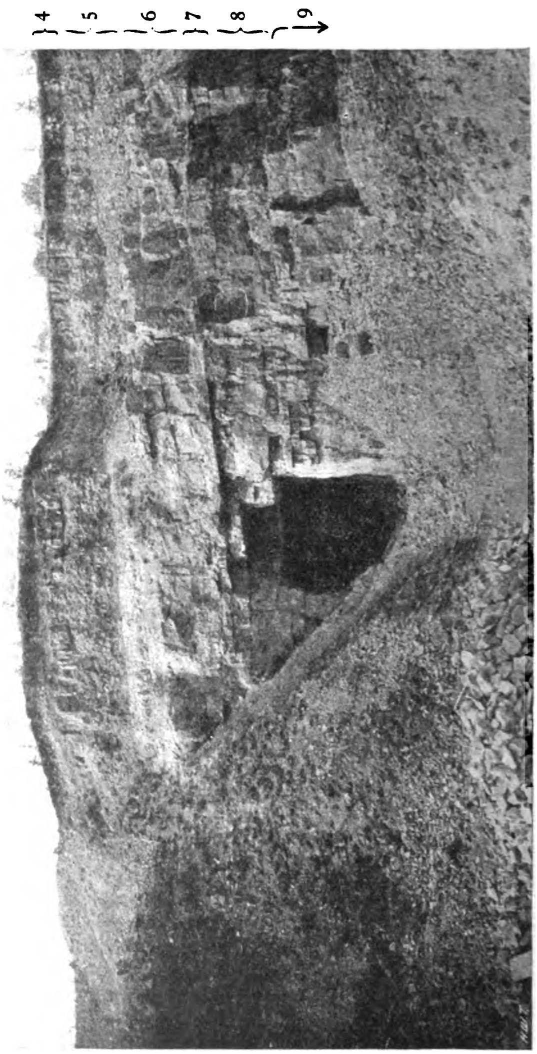

FIG. 17.—WESTINGTON HILL QUARRY (p. 395).
(From a photograph by H. W. Taunt, Oxford.)

Hill, near Winchcomb, at least 30 feet of freestone was seen above the "best yellow," and yet there were no indications of the Oolite Marl. One bed in the freestone series at the Westington Hill Quarry was found to be pierced by "borings" analogous to

those made by annelids, and in connection with this matter Mr. Richardson stated that a conglomeratic bed formed the roof of the mines in the Lower Freestone at Whittington, near Cheltenham. As this section at Westington Hill is one of the finest in the North Cotteswolds the record of the beds exposed is appended. (Fig. 17).*

WESTINGTON HILL QUARRY ABOVE CHIPPING CAMPDEN.

		Ft.	Ins.
UPPER FREESTONE.	1. Oolitic limestones, thin bedded . .		
OOLITE MARL.	2. Pale marly stone	2	0
	3. Yellow clay	2	9
	4. Hard band of limestone, grey, oolitic .	1	10
	5. Indurated pale marl, and marly stone with scattered oolite-granules. *Cidaris* (plates), *Natica cincta* (very large), *Pleurotomaria*, *Pholadomya*, *Lucina Wrighti*, *Ostrea* sp., *Alectryonia* cf. *flabelloides*, *Terebratula fimbria*. (*Ter. submaxillata*, *Ter. Whitakeri*, *Rhynchonella subobsoleta*, *Rhyn. Lycetti*, *Rhyn.* of a *subangulata*-type, *Rhyn.* aff. *parvula*, and a multitude of immature forms of *Rhynchonellæ* and *Zeilleriæ*. *Zeilleria Leckenbyi* is not uncommon, and a number of ossicles of a *Pentacrinus* were also obtained)†	9	6
LOWER FREESTONE.	6. Greyish stone, massive-bedded, rather weathered . . . about	7	0
	7. Rubbly ferruginous sandy and calcareous deposit (1 ft. 3 in. to 2 ft.) .	1	4
	8. Greyish-white, oolitic limestone, weathers into several beds . .	7	0
	9. Thick bed of yellow freestone, "false-bedded" in places	7	6
	10. Light yellowish-brown oolitic freestone, shell-débris (seen) . . .	3	7

A large number of fossils were obtained by the members, and an interesting discussion took place with regard to the "borings" and "false-bedding." The next section to be investigated was close at hand, and has been described by Mr. Buckman as being "near Campden Hill Farm.‡ In one part of the quarry rubble of *Clypeus*-grit was noticed, while the Upper *Trigonia*-grit was observed resting upon the Notgrove Freestone. The Upper *Trigonia*-grit yielded many of the usual fossils, and also a much-worn coral (*Isastræa*). The top-bed of the Notgrove Freestone was observed to be pitted, bored in

* Mr. H. B. Woodward's reading of this section, which closely agrees with the present one, will be found in the *Mem. Geol. Survey*, "The Jurassic Rocks of Britain," vol. iv (1894), p. 141. Mr. S. S. Buckman has also recorded it at p. 150 of the *Quart. Journ. Geol. Soc.*, vol. lvii (1901), but has, unfortunately, reversed the sequence, owing to an error in transcription from his note-book.

† The fossils mentioned in the brackets were not found *in situ*, but were collected from the spoil-heaps.

‡ *Vide Quart. Journ. Geol. Soc.*, vol. lvii (1901), p. 134.

places by annelids and *Lithodomi*, and to have a layer of oysters adhering to its surface. By the side of the Five Mile Drive is a quarry in the basal portion of the Tilestone, of which deposit one bed is conglomeratic, the pebbles being well rolled ; and—as certain of the members observed—the subjacent bed from which they were derived must have consolidated before the erosion. Plant-remains, an echinoid, a rolled tooth of a *Hybodus*, and a *Natica* (?) were collected. Mr. Richardson informed the members that on a previous occasion he had been told by a quarryman that about 1 foot 6 inches below the lowest bed now seen in the quarry was a "tough greenish clay," and that the lodges a little to the north of this section on the west side of the road were supplied by water from a spring "not very deep down." The water would seem to be held up by the Lower Snowshill Clay, for near the clump of beeches at a somewhat lower level were numerous gorse-bushes, which, together with other evidence, indicated the position of the Harford Sands.

The members then proceeded in the direction of Blockley, passing, near the lodge, but on the opposite side of the road, a quarry in which the *Clypeus*- and Upper *Trigonia*-grits are seen above the Notgrove Freestone, the top bed of the last-named subdivision being bored. As the section presented was similar to that investigated near Campden Hill Farm the party did not stop, but continued their walk towards Blockley, turning into a quarry opposite "The Holt." Mr. Buckman remarks that the exact position of the beds here exposed "requires more investigation," and doubtfully refers them to the Harford Sands; but Mr. Richardson thought that it was highly probable that they belonged to that subdivision, for there were several other sections in the North Cotteswolds, as in the railway cutting at Harford, near the Naunton Inn on the Stow Road, at Bourton Clump, and again close at hand, where the lithic structure of the beds exposed was very similar. Below the deposits exposed in the Holt Quarry were very clear indications of clay. Mr. Richardson explained that on a former occasion he had been informed by the quarrymen that the clay-deposit below was somewhat thick—at least 15 feet. More definite evidence was yet forthcoming, for The Holt derives its water supply from two wells sunk in the clay, and these again showed that the deposit could not be under 15 feet in thickness. Also, the sub-soil of the gardens between the houses and the road is of clay, and on the other side of the road is the quarry in the Sands with evidence of clay immediately below. Evidence of the Blockley Clay below the Harford Sands has been obtained at several other localities in the North Cotteswolds. A disused quarry completely surrounded by a wall next required attention. It showed the Tilestone dipping into the hill at a high angle, while at the western end, just below the turf, was seen the Upper

Snowshill Clay (C). Leaving the road near a barn the members saw a disused quarry in which the following evidence could be recorded.

QUARRY HALF-A-MILE WEST-NORTH-WEST OF BLOCKLEY CHURCH.

		Ft.	Ins.
TILESTONE.	1. Flaggy, shelly, oolitic stone, *Ostrea*. May have slipped a little, but not much		
LOWER SNOWSHILL CLAY.	2. Blue and yellow clays, arenaceous near the base (about) . . .	4	0
HARFORD SANDS.	3. Greyish sandstone, with small flakes of muscovite; forms a somewhat conspicuous bed	2	10
	4. Parting of rubbly stone with a little sand (1 to 4 inches) . . .	0	2
	5. Greyish-yellow oolitic stone, under-surface irregular	1	2
	6. Yellowish-brown sand, a few oolite-granules	0	7
	7. Yellowish oolitic limestone . .	1	7
	8. Yellowish parting of rubbly stone .	0	3
	9. Grey, and very slightly oolitic limestone (visible)	0	6

A little lower down the hill, and on the north side of the road, is a quarry in the Lower Freestone, so that the quarries along this road present us with facts which enable the appended section (Fig. 18) to be constructed.

From Blockley the party drove past Northwick House and by way of Paxford to Chipping Campden Station. If time had permitted a gravel-pit on the north-east side of the village of Paxford would have been visited. The pit is about 12 ft. deep, and the constituents of the gravel are mainly fragments of oolite, of which the flat fragments are arranged horizontally. Masses of flint and occasional quartzite pebbles are intermingled, and near the base of the section is green clayey matter (April, 1903). After dinner in the evening Mr. Richardson gave a lecture, dealing with the subject of earth-movements which occurred during the deposition of the Inferior Oolite.

After making some general remarks on the physical geography towards the close of the Harpoceratan Age, the lecturer observed that all through the Ludwigian and Sonninian Ages there is distinct evidence that there were continuous upheavals along the tract of country now indicated by the Moreton Valley. Low down in the Inferior Oolite Series there is evidence that what may be called the Lower Limestone* rests non-sequentially upon

* This term was originally applied by E. Witchell to those non-pisolitic beds, which, as a rule, are present between the *scissum*-beds and typical Pea-grit of the Stroud-Cheltenham District. It must be admitted, however, that the line of division is somewhat arbitrary, for almost any beds between the deposits of the hemera *scissi* and Lower Freestone may be pisolitic at one locality, and non-pisolitic at another.

the Cotteswold Sands, for in the side of the road near Copse Hill House such is seen to be the sequence, this Lower Limestone being distinguished by the occurrence of a certain small Pecten. There is no evidence of the *scissum*-beds, such as are seen above the Cotteswold Sands at Broadwater, near Temple Guiting, and at Wood Farm near the same village—sections situated in a synclinal area. The relationship then of the *scissum*-beds and Lower Limestone to the Cotteswold Sands may be diagrammatically represented thus (Fig. 19, (2)). Although there is evidence of a pene-contemporaneous erosion during the deposition of the Lower Freestone the non-sequence is not apparently of importance, but after the formation of that rock the movement along the Moreton anticline must have again taken place, for in a quarry at Wagborough Bush (see p. 404) the *Tatei*-bed of the Upper Freestone rests directly upon the Lower Freestone—the Oolite Marl is missing. This probably means that owing to the elevation of the Lower Freestone before the *bradfordensis* hemera the Oolite Marl was not allowed to accumulate at the spot, but was, nevertheless, being deposited during the first part of the hemera in more depressed areas: this theory seems more probable from the facts obtainable than that of deposition and subsequent erosion. The Lower Free-

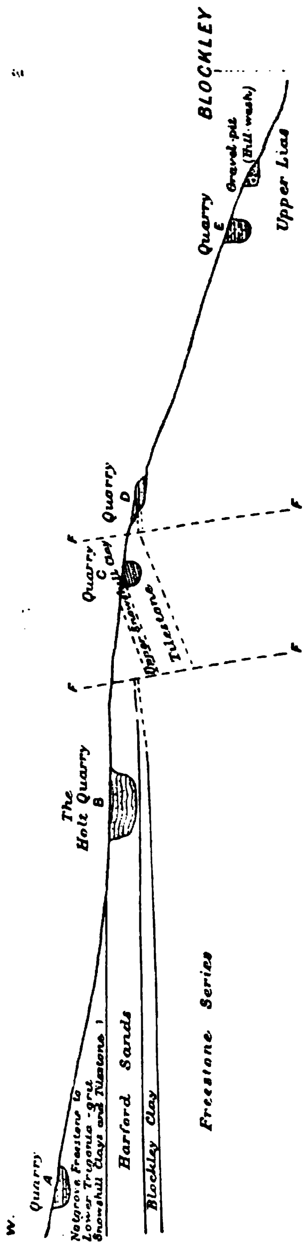

FIG. 18.—SECTION TO SHOW SEQUENCE OF INFERIOR-OOLITE DEPOSITS IN THE NEIGHBOURHOOD OF BLOCKLEY, NORTH COTTESWOLDS.

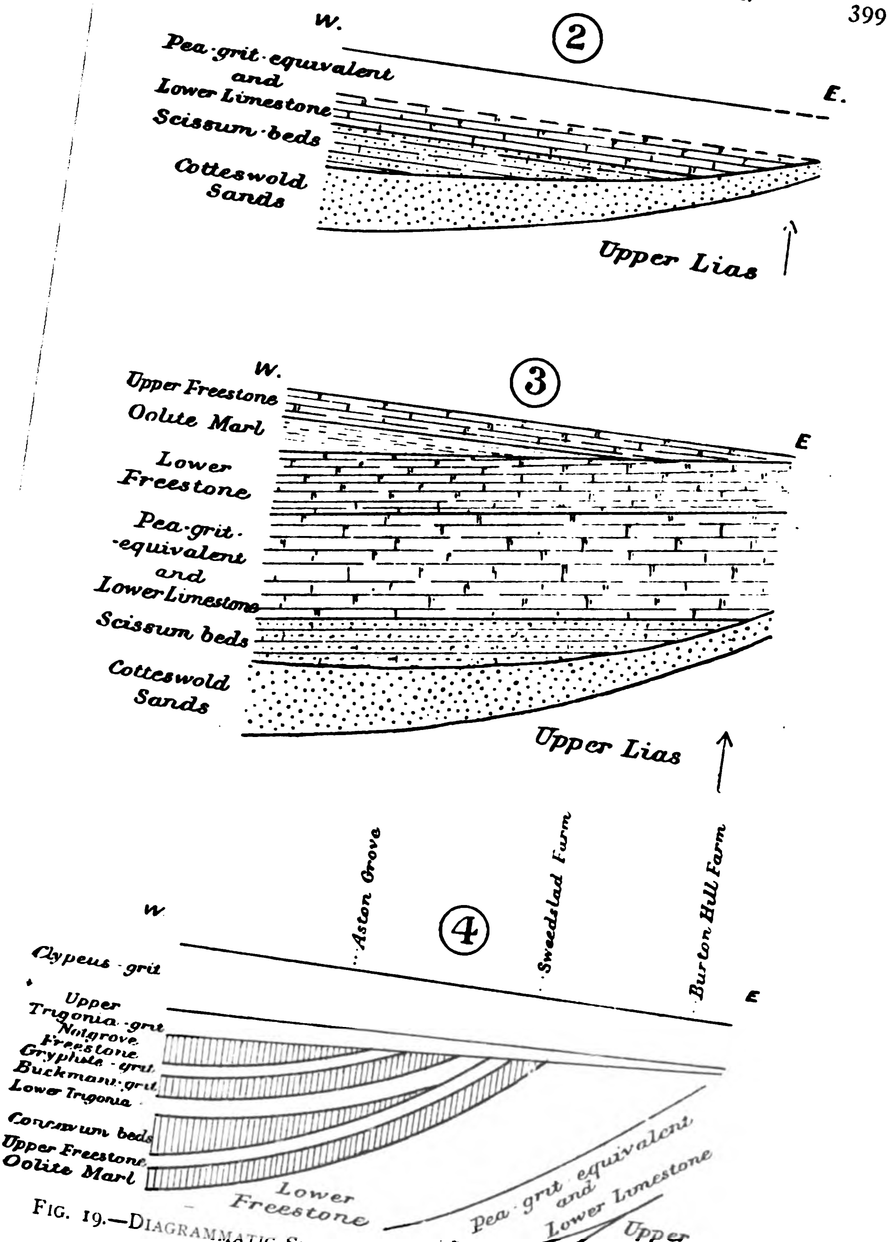

FIG. 19.—DIAGRAMMATIC SECTIONS (see pp. 398-400, and "Errata" note, p. 408).

stone now seen in this quarry, however, was submerged at the commencement of the time when the Upper Freestone was laid down, for, as already stated, the *Tatei*-bed rests non-sequentially upon the Lower Freestone. Matters then may be represented as shown diagrammatically in Fig. 19, (3). During the hemera *concavi* several slight movements of elevation along the Moreton anticline took place, as is shown by the relationship of the several deposits of that date to one another, and to the Upper Freestone. After that hemera there is no evidence as yet of any important movement, although—as was noticed by some of the members—in the Gryphite-grit exposed in the quarry (p. 391) near the Monument, on Broadway Hill, there is a shaly deposit full of well-rolled pebbles. But in post-*Sauzei*, and certainly not later than the *Garantianæ* hemera, there was a great upheaval along the anticlinal axes; and especially along that old line of weakness—the country now indicated by the Moreton Valley. The results of the forces causing the earth-movements were to throw the strata into anticlinal and synclinal flexures, and in the district visited by the Association we have to deal with a portion of a syncline gradually passing up into an anticlinal fold. After this flexing of the strata we must picture the Ragstone-beds (Lower *Trigonia*-grit to the *Phillipsiana*-beds, and possibly strata laid down during the *niortensis* and *Humphriesiani* hemeræ) thrown into the positions indicated in Fig. 19, (4); their upturned edges denuded; gradual subsidence; the deposition of the Upper *Trigonia*-grit; the probable slow overlap of the eastern limit of this deposit by the *Clypeus*-grit; and the possible complete submergence of the Moreton anticline. The statement, "the probable slow overlap of the *Clypeus*-grit," is employed because the top-bed of the Upper *Trigonia*-grit is often bored by *Lithodomi* and covered with *Ostreæ*, and that may point to another pene-contemporaneous erosion, brought about by a slight repetition of the movement of upheaval along the anticlinal axes, whereby the area along the Moreton Valley was again elevated, causing the *Clypeus*-grit to overlap the Upper *Trigonia*-grit, and that there is such an overlap is certain. Near the barn north of Kates Britton, near Little Rissington, there is a quarry in the *Clypeus*-grit yielding *Clypeus Ploti*, *Terebratula globata*, *Lima gibbosa*, *Myacites*, etc., whilst at a slightly lower level nearer the barn a spring bursts out—thrown off the Upper Lias clays. Reference to Table I. will show what a great mass of rock is missing at this locality, most probably all the Upper *Trigonia*-grit; certainly the subdivisions from that deposit downwards to the *scissum*-beds, and inclusive of the last-named deposit, and there is no evidence of the Cotteswold Sands. When the student has studied the well-known sections at Leckhampton and Cleeve Hills, and has visited this locality near Little Rissington, then will he comprehend fully the magnitude of the break.

FIG. 1. NORTHERN DRIFT ON LIASSIC CLAY, BREDON STATION.
From a photograph by Miss Mary S. Johnson.

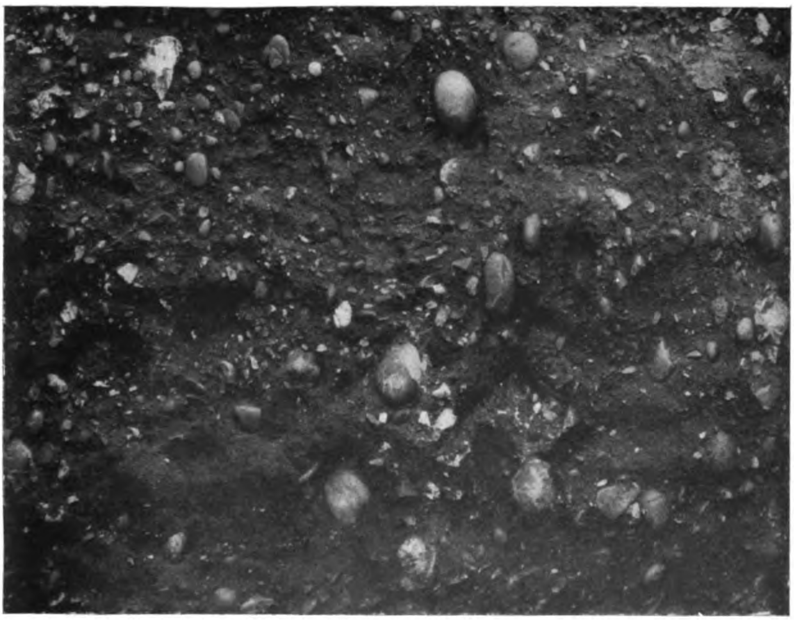

FIG. 2. GRAVEL PIT, MORETON-IN-MARSH.
(From a photograph by Mr. S. S. Buckman; by permission of the Cotteswold Naturalists' Field Club.)

TABLE I.—THE INFERIOR OOLITE SERIES (COTTESWOLD HILLS).*

Geological Survey.		Approximate Zonal Terms used by Wright and Witchell.	Stratigraphical Terms	Chronological Terms (After S. S. Buckman). Hemera.	Age.	Epoch.	Renevier's Chronographic Subdivisions.
Inferior Oolite Series.	Upper Stage.	*Parkinsoni*-zone.	Limestone beds above the *Clypeus*-grit (White Limestone).	*fuscæ.* *zigzag.*	Parkinsonian.	Stepheoceratidan.	Bathonian.
			Clypeus-grit. Upper *Trigonia*-grit.	*Truellii.* *Garantianæ.*			
			non-sequence.				
		Humphriesianum-zone.	*Phillipsiana*-beds. *Bourguetia*-beds.	*Sauzei.*	Sonninian.		Bajocian.
			Witchellia-grit. Notgrove Freestone.	*Witchelliæ.*			
			Gryphite-grit. *Buckmani*-grit. Lower *Trigonia*-grit.	*Sonniniæ.* Post-*discitæ.* *discitæ.*			
			Upper Snowshill Clay. Tilestone.† Lower Snowshill Clay.† Harford Sands. Blockley Clay.†	*concavi.*	Ludwigian.	Arietidan.	Aalenian.
	Lower Stage.	*Murchisonæ*-zone.	Upper Freestone. Oolite Marl.	*bradfordensis.*‡			
			Lower Freestone. Pea-grit. Lower Limestone.	*Murchisonæ.*			
			scissum-beds.	*scissi.*			
		opalinum-zone.	*opaliniforme*-beds. *aalensis*-beds. *Moorei*-beds.	*opaliniformis.* *aalensis.* *Moorei.*			

* Extracted from "A Handbook to the Geology of Cheltenham and Neighbourhood" (1904), Table iii. † Found only in the North Cotteswolds. ‡ Over a considerable portion of the district there is a non-sequence between (1) the deposits of the hemerae *discitæ* and *bradfordensis*; and (2) between, apparently, the deposits of the hemera *scissi* and the subjacent beds.

April 4th.

On the Monday the members proceeded to Moreton-in-Marsh by train, and found brakes awaiting them. The first halt was made to examine the exposures in the road-cutting about a mile to the north of Stow-on-the-Wold. First of all an opening on the left-hand side of the road revealed yellowish oolitic iron-stained rock with a little sandy matter, while on the other side was observed flaggy-oolitic limestone. The exact stratigraphical position of these beds is a little difficult to fix, but they most probably belong to the upper portion of the Pea-grit equivalent and the base of the Lower Freestone. Immediately above was seen the *Clypeus* grit, exhibiting its typical lithic structure and crowded with specimens of *Clypeus Ploti*; *Ostrea* cf. *gregaria*, *Rhynchonella* aff. *hampenensis*, and *Terebratula globata* were also collected. The *Clypeus*-grit then passes up into somewhat unfossiliferous – but distinctly oolitic—limestones, in which, however, a single specimen of *Clypeus Ploti* and two or three *Terebratulæ* of the *globata*-type were found. Separating this rock from strata, which closely resembled in appearance the basement-beds of the Great Oolite, was an intermittent deposit of grey and yellowish clay with oolite-granules, and containing lignite, a few pebbles, and specimens of *Ostrea*. Soft oolitic stone often replaces this clayey deposit.

Between Stow and Bourton-on-the-Water a gravel-pit was visited. There are two pits somewhat close together, and it was the northernmost that was investigated. The section showed about 12 feet of gravel composed of débris of Liassic and Inferior Oolitic limestones with derived specimens of *Gryphæa* "*sublobata*," *Zeilleria*, *Serpula*, *Alectryonia flabelloides*, *Rhynchonella*, and an echinoid. One small fragment of flint was found *in situ*. Layers of dark gravel traverse the section irregularly, and on closer inspection this was found to be due to the presence of carbonaceous matter which coated the pebbles; and there were small patches of clayey matter. Mr. Richardson explained that the accumulation was essentially a local one, all of the constituents having been derived from the North Cotteswolds, and he commented upon the apparent absence of any foreign or "Northern Drift" pebbles in the Vale of Bourton. He made mention of other sections of gravel of similar composition near Sherborne, some four miles to the south of Bourton, where the débris is noticeably rolled. As the sections referred to are very little known their exact positions may be given: the one is distant about half-a-mile in an east-north-easterly direction from Sherborne Church; and the other five-twelfths of a mile east of Farmington Church—the latter a particularly interesting section.

Passing under the railway-line to the west of Bourton the members ascended the hill, and taking the first turn to the left

saw a quarry opened out in rock belonging most probably to the Pea-grit equivalent. The section showed that the mapping of the different formations as represented on the Geological Survey Map required some rectifying. The next section examined was near Bourton Hill Farm, Clapton.

QUARRY NEAR BOURTON HILL FARM, CLAPTON.

		Ft.	Ins.
Clypeus-GRIT.	1. Rubble		
UPPER *Trigonia*-GRIT.	2. Grey, shelly ragstone; *Terebratula globata* (very numerous), *Acanthothyris spinosa* (rare), *Rhynchonella hampenensis*, *Avicula digitata*, *Lucina* cf. *clypeata*, *Pecten* cf. *demissus*, *Ostrea* aff. *acuminata*, *Ostrea* sp. . . . about	0	6
LOWER FREESTONE.	3. Rubbly, brownish-grey, in places slightly ironstained, oolitic limestone. Top bed slightly bored and covered with *Ostreæ*	3	8
	4. Greyish-yellow oolitic limestones: an intermittent bed 1 ft. 4 ins. to 2 ft. 4 ins. thick; is almost wholly made up of Polyzoa and shell-débris . . . . visible	12	0

After pointing out the sequence shown in this quarry Mr. Richardson stated that as the members proceeded westwards they would see other beds coming in below the grit. This statement was borne out by the next quarry visited at Sweedslad Farm, where the Oolite marl was observed below the grit.

QUARRY AT SWEEDSLAD FARM, NEAR CLAPTON.

		Ft.	Ins.
Clypeus-GRIT.	1. Rubbly rock with typical lithic structure—pisolite-spherules; *Terebratula globata*, *Pecten* cf. *demissus*, *Myacites*, *Homomya gibbosa* . .	1	4
UPPER *Trigonia*-GRIT.	2. Grey, slightly shelly rock, sandy; *Ostrea*, *Ter. globata*. *Ter. globata* is most abundant in the upper portion, and occurs in association with a *Rhynchonella*, but the lower portion is not very fossiliferous .	3	10
OOLITE MARL.	3. Brownish clay, oolite-granules . .	0	5
	4. Oolitic limestone	0	11
	5. Brownish clay, with a bed of oolite in places	0	8
	6. Whitish oolite, becoming rubbly at the base, and passing down into white and yellow marl with *Ter. fimbria* and *Rhyn. subobsoleta* . . .	2	10
	7. Whitish oolite, rubbly at the top; *Ter. fimbria*, *Lucina Wrighti*, *Natica cincta*, *Pholadomya*. Some of the oolite-granules are brownish, rock more compact below. visible	3	4

The explanation of the "incoming" of the Oolite Marl seems to be that, whereas near Bourton Hill Farm the anticlinal flexure, having its strike probably along the Vale of Bourton, caused the Oolite Marl by elevation to be eroded, here in the synclinal area at Sweedslad that rock was for the greater part preserved.

Near the place where the members boarded the brakes on the Roman Foss Way (about half-a-mile to the north of the Sweedslad section) a large quarry in the *Clypeus*-grit was noticed, and the considerable thickness of the grit in this neighbourhood was commented upon.

While in the brakes the members had lunch, so that upon arrival at the railway-bridge they were ready to continue the walk without any delay. At Wagborough Bush two quarries were seen, and the southernmost was entered. Here the sequence of deposits was as follows:

QUARRY AT WAGBOROUGH BUSH, NEAR BOURTON-ON-THE-WATER.

		Ft.	Ins.
Clypeus-Grit.	1. Rubbly rock with pisolite spherules; *Rhynchonella* spp., *Modiola*, *Terebratula globata*, *Ter. permaxillata*, *Myacites*, *Pecten demissus*, *Pecten* sp., *Lima gibbosa*, *Pholadomya*, *Clypeus Ploti*, *Astarte*, large *Ostreæ*, gasteropods . . . . about	5	6
	2. Ironstained, shelly, slightly oolitic limestone, passes up into typical *Clypeus*-grit. *Rhynchonella Tatei* (probably derived) at base . .	0	9
Upper Freestone.	3 Rubbly yellowish deposit; *Ostreæ* in places on upper surface; *Rhynchonella* cf. *subobsoleta*, *Rhyn. Tatei*, *Terebratula fimbria* (5 to 12 in.) .	0	8
	4. Yellowish-white oolite; *Terebratula fimbria* (rare), *Rhynchonella Tatei* (12 in. to 1 ft. 7 in) . . .	1	3
	5. A greyish and yellowish rubbly deposit, clayey in places; full of *Rhynchonella Tatei*, *Rhyn.* cf. *subobsoleta*, *Terebratula fimbria* (0 to 6 in.) . .	0	3
Lower Freestone.	6. Hard stratum of limestone, makes a conspicuous feature	0	8
	7. Massive-bedded limestones; the higher beds are the most oolitic. *Terebratula fimbria* 4 ft. 1 in. below the top-bed of the Lower Freestone . . . . about	8	0

Particular attention was drawn to the fact that there was evidence here of two non-sequences. The *Tatei*-bed* rests directly upon that Lower Freestone, and that means that the Oolite Marl, a deposit which the members investigated at

* The stratigraphical position that the *Tatei*-bed occupies, where the sequence is complete, may be seen by reference to the *Quart. Journ. Geol. Soc.*, vol. li (1895), p. 400.

Snowshill and Westington Hill, is wanting; and the *Clypeus*-grit reposes upon the Upper Freestone. Now the former non-sequence, it was explained, was probably due to an elevation in immediate pre-*bradfordensis* times, whereby the Oolite Marl was not allowed to accumulate at this spot, the Lower Freestone not being submerged until the formation of the deposit containing the specimens of *Rhynchonella Tatei*, while the phenomenon of *Clypeus*-grit resting upon the Upper Freestone is to be explained by the theory of the Bajocian Denudation.

Passing through the picturesque village of Upper Slaughter the members ascended the hill to the north-east, and saw traces of the Cotteswold Sands in the left bank of the road, while above was the Lower Limestone—there being no signs of the *scissum*-beds. Opposite the entrance to Copse Hill House a quarry reveals the *Clypeus*-grit resting upon about 4 feet of Lower Freestone, and this latter rock upon the Pea-grit equivalent. The top-bed of the Lower Freestone, it was stated—for time did not permit of the examination of the section—was bored, and had *Ostreæ* adhering to its surface. In a little wood by the side of the Stow Road a most interesting section was investigated. The beds exposed comprised sand, clay, and limestone, and belonged to the highest subdivision of the Inferior Oolite Series—the Chipping Norton Limestone. One bed of limestone interstratified in the clay yielded a number of gasteropods, but they were mostly in a bad state of preservation. A short distance down the hill, in the direction of Lower Swell, was the last section to be visited this day; the deposit exposed was almost entirely made up of the valves of an *Ostrea* of the *Sowerbyi*-type. Mr. Richardson said the rock belonged to the Great Oolite Series,* and compared it with the deposit seen about the Stonesfield Slate-equivalent at Grove's Quarry, Milton. He had found *Rhynchonella concinna* in the strata the members were studying: a "find" which was shortly confirmed. At Stow the brakes were waiting to convey the party back to Moreton.

April 5th.

The morning of the last day was occupied in investigating the country around Batsford. At Bourton-on-the-Hill the large quarry was visited, and the beds constituting the Pea-grit equivalent examined. The contemporaneity of the deposit with the true pisolite of the Cheltenham district was shown by the members finding certain Polyzoa, *Pseudoglossothyris* (*Terebratula*) *simplex*, *Terebratula submaxillata*, and a little *Terebratula* of a type well known at Crickley Hill in the highest beds. Mr.

* Clays at the base of the Upper Division of the Great Oolite in Mr. H. B. Woodward's record, *vide Mem. Geol. Surv.* "The Jurassic Rocks of Britain," vol. iv (1894), p. 307.

Richardson has also recorded *Rhynchonella subangulata,* and *Zeilleria circularis.*

The Bourton-Clump section, described by Mr. S. S. Buckman,* was somewhat overgrown, but the Harford Sands and Lower Snowshill Clay could be clearly seen. In a field to the north of Batsford Park (the third from Blockley Downs Farm in a north-easterly direction), and at an altitude of about 750 feet, an old excavation showed the Cotteswold Sands and Upper Lias clay. Attention was drawn to the fact that here the Upper Lias occurred at a height of about 750 feet above Ordnance-datum, while to the west of Condicote—in a synclinal area—the top of the Stonesfield Slate Beds was shown by the 6-inch map to be under 699 feet above Ordnance-datum. This it was explained was due to the continuous elevation of the Moreton anticline, and the corresponding depression of the country around Condicote. Descending Cadley Hill the walk was continued along the platform caused by the "rock-bed" of the Middle Lias; and when the members were passing through Aston Magna the junction of the sandy clays of the Middle Lias with the Lower Lias clays (according to the *Geological Survey*), was practically illustrated by the outburst of a little spring in the middle of the road. A clay-pit in deposits of the hemera *armati* was visited, but very few fossils were obtained. A walk across the fields brought the members back to Moreton-in-Marsh.

Here they met Dr. C. Callaway, M.A., F.G.S., under whose guidance the gravel-pits were examined after lunch at the "Royal White Hart Hotel." On arriving at the gravel-pits, lying about half-a-mile east of Moreton-in-Marsh, Dr. Callaway pointed out that these deposits, situated near the water-parting between the basins of the Thames and the Severn, were over 400 ft. above Ordnance-datum. They consisted mainly of flints, not much worn, and well-rounded pebbles of quartzite in a sandy matrix, which in places lay in horizontal layers. Many of the flints and pebbles were in a vertical position, and some of them had their larger end uppermost (Plate XLI, Fig. 2). Similar flints and pebbles were scattered abundantly over the valley to the north; but in the valley of the Evenlode to the south these materials were less plentiful. Three or four miles to the east the late W. C. Lucy had found fragments of red chalk in gravel. Some of these were exhibited, and were identified by Mr. Whitaker. The speaker referred to the previous visit to these pits by the Cotteswold Naturalists' Field Club, when great diversity of opinion was expressed on the origin of the gravels. Mr. T. Melland Reade had favoured the theory of conveyance by floating ice during a period of marine submergence. Mr. S. S. Buckman had admitted the agency of ice, but held that the

* *Quart. Journ. Geol. Soc.* vol. lvii (1901), p. 135.

materials of the gravel had been brought down by a large river in the Pliocene epoch. The speaker had objected to the river theory as making too large a demand upon time. He contended that a simpler and more natural explanation was found in the southward drift of ice in the Glacial Epoch, a fact which all admitted; but he was not prepared to decide between the claims of floating ice and ice moving over the land. To these opinions he still adhered.*

Opportunities were also afforded the members for visiting Tewkesbury and Malvern. Those who went to Tewkesbury drove along the road to that locality as far as Teddington Cross, but here they turned up the lane for Overbury. A sand-pit by the side of the lane was visited, and it was seen that the main mass of the deposit was of quartzose sand, with a little débris of limestone derived from the Inferior Oolite and Lias, and an occasional "Northern Drift" pebble. Mr. Richardson pointed out that this was one of the few sections where conspicuous clay-bands were intercalated in the superficial deposit, but owing to the water in the pit it was not possible to investigate them. Driving into Overbury the gravel-pit—which yielded Mr. S. S. Buckman most of the evidence whereby he was enabled to demonstrate that, during the greater number of the hemeræ during which the Cotteswold Sands and Cephalopoda-bed were being laid down in the Haresfield district, clay (with a few limestone-nodules) was being deposited in the Bredon area—was visited, but no "finds" of importance were made.† The material worked in this pit is the product of the excavation of the valley in Overbury Park close at hand. At Bredon Station a most interesting section was examined (Plate XLI, Fig. 1): it showed the "Northern Drift" resting upon an undulating surface of the Liassic clays, and the members present expressed their concurrence with the view that the surface of the clay had not been eroded by marine action; if it had been that surface would have been much more even. The date of the clay excavated during the construction of the siding was stated by Mr. Richardson to be of the hemeræ *stellaris* and *obtusi*.

At Tewkesbury the Abbey was visited, and the fine west front greatly admired. Afterwards the members proceeded to the Mythe Hill, where in the picturesque cliff by the side of the Severn is a fine section of the Upper Keuper Marls.

In a cutting through which the Tewkesbury-Ledbury road passes at Sarn Hill was an exposure of the Rhætic Bone-bed. At first the contemporaneity of this micaceous sandstone, which contains but very rarely a fish-scale, with the well-known Bone-bed of Aust and Garden Cliffs, might be doubted, but it was pointed out that in the cliff-section at Wainlode, near Gloucester,

* This paragraph was supplied by Dr. C. Callaway.
† *Vide Quart. Journ. Geol. Soc.*, vol. lix (1903), pp. 445 *et seq.*

the change might be studied: at one end of that cliff it was a thin pyritic stratum full of fish-scales, and at the other a non-ossiferous micaceous sandstone a foot thick.

In a wood near the cutting two disused quarries in the Lower Lias were visited; the first revealed the *Ostrea*-beds, which may be dated as pre-*planorbis*; the second, deposits of the hemera *planorbis*, crowded with the characteristic ammonite at certain horizons.

After tea at the "Swan Hotel" the members drove back to Evesham.

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ERRATA.—Note, in Fig. 19 (4) "Bourton" should replace "Burton," and the word "grit" should follow "Lower Trigonia."

EXCURSIONS TO THE FARNHAM GRAVEL PITS ON APRIL 23RD, AND TO THE BRICKFIELDS AND GRAVEL PITS AT DAWLEY, BETWEEN HAYES AND WEST DRAYTON, ON APRIL 30TH, 1904.

Directors: H. A. MANGLES, F.G.S., R. FANE DE SALIS, F.G.S., AND H. W. MONCKTON, F.G.S.

Excursion Secretary: GEORGE W. YOUNG.

(*Report by* H. W. MONCKTON.)

The main object of these two excursions was to enable the members to compare the Drift Deposits of a plateau which now overlooks all the valleys around it, with those of a plain not much above the bottom of a modern valley.

The Drift at Farnham consists of gravel, and there is a bed of gravel overlain by brickearth at Dawley. In both places the gravel has yielded many flint implements.

On April 23rd the members assembled at Farnham Station, and proceeded by carriage, motor, or cycle to the extensive gravel pits at the north-eastern end of the plateau, a little south-east of Farnham. Some account of the sections will be found in the report of our excursion to Farnham on May 13th, 1893, and as that was a whole day excursion the members were able to see much more of the geology of the neighbourhood than time would allow of on the present occasion. I may, however, take this opportunity of recording the find of *Ammonites mammalatus* in bed 5 of the section at Wrecclesham given on page 76 of that report (*Proc. Geol. Assoc.*, vol. xiii). I found a specimen soon after our excursion in 1893. After an examination of the gravel pits the party followed the road past Waverley Abbey and Crooksbury Hill to Littleworth Cross, the residence of Mr. Mangles, where a collection of implements from the Farnham gravels was exhibited. The members then walked round Mr. Mangles's beautiful garden, and inspected his magnificent collection of Himalayan Rhododendrons, most of which were in full blossom. He has since received two awards of merit from the Royal Horticultural Society for them. The party was then entertained to tea by Miss Mangles, and afterwards returned to London by way of Tongham and Guildford.

A vote of thanks to the Directors and to Miss Mangles was proposed by Dr. A. E. Salter and carried unanimously.

On April 30th the party met at Hayes Station, and walked along the towing-path of the Grand Junction Canal to Dawley.

There some excellent sections in the Drift were inspected, and Mr. De Salis explained that it consisted of brickearth resting upon gravel. The ground is let to brickmakers, who first work off the brickearth and send the bricks by canal to London.

The bricks are made of a mixture of brickearth, ashes, and chalk. They are first sun-dried, and then stacked in kilns and burnt. The brickearth having been removed the gravel is then sold at so much an acre, and worked to within a foot of the water level.

The gravel is much more sandy on the east side of the Dawley Estate than on the west side, and both the sandy phase and the stoney phase of the deposit have a considerable commercial value. Where, however, the sand and stones are mixed the value is much reduced.

Numerous flint implements recently found from 12 ft. to 18 ft. below the surface were shown to the members by the workmen. One unusually fine specimen measured 10 in. in length, and weighed $3\frac{1}{2}$ lbs.

A vote of thanks to the Directors was proposed by Prof. J. F. Blake and was carried unanimously.

The party then walked to West Drayton Station and returned to London.

The gravel-capped plateau south of Farnham which we visited on April 23rd is a long spur running out from the rather high ground of Alice Holt Forest. The top is fairly flat, and slopes from a level of about 380 ft. in the south-west to about 360 ft. in the north-east. There are deep valleys on both sides of the plateau. The Drift-covered area at Dawley is about 115 ft. above the sea, and it is part of a tolerably gradual slope extending from Hillingdon, where the level is 188 ft., down to the River Thames, some 30 ft. above sea level. There are slight features in this slope enabling one to divide it into terraces, but these terraces are not very well marked, and the covering of Drift is practically continuous. The thickness of the gravel is up to 25 ft. at Farnham, and from 12 to 15 ft. at Dawley. At both places it is better stratified at the bottom than at the top, and this is usually the case with the gravels of the district. The Dawley gravel is covered by a more or less continuous bed of brickearth, but there is no brickearth at Farnham.

At both places the gravel consists largely of subangular flints, and is thus easily distinguished from the Eocene pebble beds of the London District. It is indeed hard to match such subangular deposits in any of the older geological formations, and I have suggested that these gravels were possibly deposited as the result of earth-movements of elevation, whereas most of our geological deposits are due to long and continuous earth-movements of depression (see *Proc. Geol. Assoc.*, vol. xvi, p. 443). In any case

I feel convinced that the Drift at both places is the deposit of rivers, and as the gravel in both cases contains fragments from the Hythe Beds of the Lower Greensand, the drainage area of the rivers must have changed considerably since the date of deposit. Thus the Wey and its tributaries does not drain a Hythe Bed area until after it has passed the Farnham plateau, and the Thames does not drain such an area until it has passed Dawley. Moreover, Dawley is now north of the present course of the Thames, and the Hythe bed fragments have almost certainly been brought from the Wealden district a long way to the south of the river.

I was much interested by the remarks on the Thames Valley Drifts by Mr. Pocock at Grays last year (*Proc. Geol. Assoc.*, vol. xviii, p. 143), and I much appreciate his account of those deposits in the Summary of *Progress of the Geological Survey* for 1902, p. 199. I should like also to take this opportunity of congratulating the Survey on the excellent colour-printed map of the London District just issued.

When we were at Ipswich in 1902 I gave a summary of the events which seemed to have happened in that district in recent geological times, and I will now attempt to give a similar summary for the Farnham-Dawley district.

LOWER BARTON.—The yellow sands of the Fox Hills, Chobham Ridges, Easthampstead Plain, etc., are shown by their fossils to be of Lower Barton age. The shells are marine, and the valves of the bivalves are united and closed, and probably the sands were deposited in a wide bay of open sea not far from land.

MIDDLE AND UPPER BARTON.—Wanting.

OLIGOCENE.—Wanting.

MIOCENE.—The folding which gave rise to the anticline of the Weald, and the syncline of the London Basin, probably took place to a great extent in this period, though the movements continued into Pliocene times.

PLIOCENE.—Netley Heath on the North Downs is covered by a deposit of sand in which Mr. Stebbing has found casts of shells, and there seems every probability that the deposit is of the age of the Lenham Beds, *i.e.*, Older Pliocene (*Proc. Geol. Assoc.*, vol. xvi, p. 524). Netley Heath is now 650 feet above the sea, so that elevation of that part of our district to an extent of some 700 feet has apparently taken place since the early Pliocene.

It does not follow that the sea extended much to the north or west of Guildford during this period, and the western part of the syncline of the London Basin, and much of the present drainage area of the Thames may have become dry land at any time after the Lower Barton, and it is therefore possible that the rivers are older than the completion of the foldings. What

effect the earth movements may have had on the course of the rivers is consequently a question of some importance; possibly no very great effect, for the strata are so soft that in case of elevation of a tract of ground the water might cut its way fast enough to keep pace with the earth movement.

We thus see that part of the present drainage area of the Thames may have been land since pre-Pliocene times, and neither the area of the syncline of the Thames nor the anticline of the Weald appear to have been submerged since the early Pliocene. I propose to divide the land history of the district into eight stages.

THE LAND HISTORY OF THE DISTRICT.

Stage 1. The Sarsen Stones are probably the relics of the first land surface after the marine Lower Barton (*Proc. Geol. Assoc.*, vol. xviii, p. 184).

Stage 2. Completion of the elevation of the Weald in Pliocene Times.—The depression of the Rhine syncline extended to Norfolk, and the elevation of the Weald may have been accompanied by a depression of the London Basin, but, however that may be, it was not submerged. The deposition of the river gravel with large flints at Upper Hale and Cæsar's Camp, Aldershot, and on the North Downs at Newland's Corner, etc., belongs to this period.

This is also the probable date of the Pebble Gravel of the Chiltern Hills.—If I could be certain that the material of this Pebble Gravel came from the west I should suspect it to be the earliest gravel of the River Thames.

Stage 3. A slight elevation of the Thames syncline appears to have taken place, and considerable sheets of gravel were in consequence deposited. The gravel of Goring Heath, Cane End, etc., is Thames Gravel of this date, and on Bucklebury Common we find the corresponding gravel of the Kennet, and on Chobham Ridges, etc., the gravel of the Blackwater, with much Hythe Bed material and many Sarsen stones, relics of the older surface.

Stage 4. The Chalky Boulder Clay.—This deposit is newer than the gravel which underlies it at Finchley, etc., and which contains both northern or western material and Hythe Bed fragments, and it is older than the stratified sand and gravel which rests on it at Hornchurch at a level of a little above 100 ft. O.D. I consequently put it a little before the 100 ft. terrace of Mr. Pocock.

Stage 5. The Dawley Gravel and the 100 ft. terrace.—The Thames appears to have followed the line of the present Great Western Railway from Maidenhead in the direction of Dawley. I do not agree with Mr. Pocock in thinking that the river was ten miles wide at Southall, for the stratified gravel at the

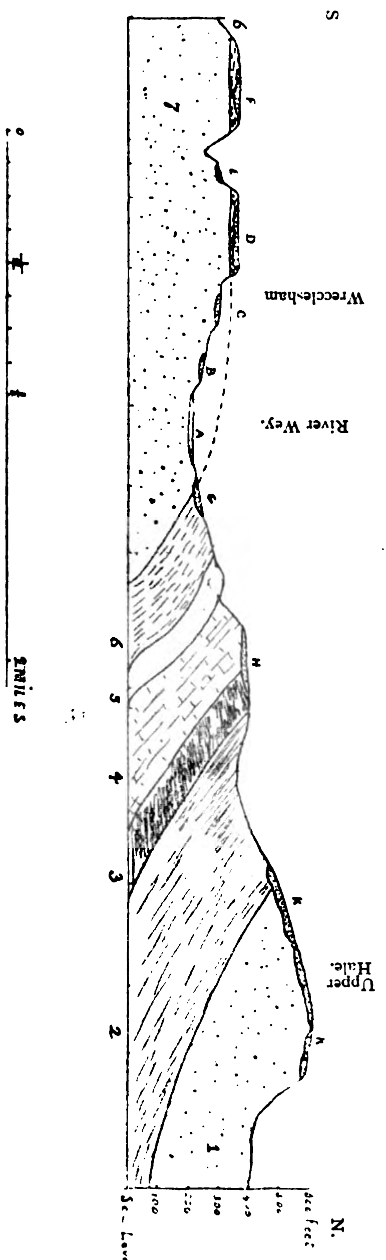

FIG. 20.—SECTION THROUGH UPPER HALE AND WRECCLESHAM A LITTLE WEST OF FARNHAM.—*H. W. Monckton.*

A. Alluvium of the River Wey. B to H. Various patches of gravel. K The high level gravel of Upper Hale and Cæsar's Camp, Aldershot.

1. Bagshot Beds. 2. London Clay. 3. Reading Beds. 4. Chalk. 5. Upper Greensand. 6. Gault. 7. Lower Greensand.

100 ft. level at Weybridge is not a Thames gravel, there being no northern stones in it. It is a gravel of the River Mole.

Stage 6. The gravel of the plain between Brentford and the River Coln about and a little over 50 ft. O.D.

Stage 7. The *Corbicula fluminalis* beds of Grays and Crayford.—The gravel between Sunbury and Shepperton, and the patches of brickearth near Shepperton, all about 40 ft. O.D., are probably newer than the Grays and Crayford shell-beds.

Stage 8. The alluvium of the River Thames.

It will be seen that I place the implementiferous gravel of Dawley after the Chalky Boulder Clay, and I think that this is probably correct, but I am far from certain where I ought to place the gravels with implements of Farnham and of the plateau at Sonning, near Reading. They come after my third series of deposits, and before my sixth series, and they may be equivalent to the Dawley Gravel, or they may come before the Chalky Boulder Clay. Possibly the form of the implements themselves may assist to solve this question.

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EXCURSION TO HENLEY-ON-THAMES.

SATURDAY, MAY 7TH, 1904.

Director: H. J. OSBORNE WHITE, F.G.S.

Excursion Secretary: MISS M. C. FOLEY, B.Sc.

DESPITE the threatening aspect of the sky during the earlier part of the day, this excursion was fairly well attended; about twenty members and friends of the Association gathering at Henley Station shortly after one o'clock.

Passing through the town to Northfield End, the party took the footpath leading over No Man's Hill to Henley Park. From a spot near the large tumulus known as The Mount, the Director indicated the more prominent physiographical features of the

surrounding country, and briefly discussed their relation to the structure of the rocks out of which they had been carved. It was remarked that No Man's Hill was a spur of chalk lying between the Thames and Assenden valleys, and that its flat, gravel-capped summit, which made a noticeable angle with the sloping surface of the higher ground to the north, was most probably the work of the Thames when it flowed at rather more than 200 feet above its present level. This gravel-flat was a good example of the terraces which were to be found in large numbers, and at many levels above the river, between Reading and Maidenhead. Owing to the lateral discontinuity, and often much degraded condition, of these terraces, the attempts so far made to correlate them had not proved satisfactory, but it had been observed that they were better marked, or more common, at

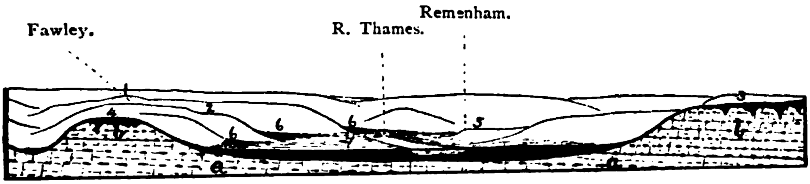

FIG. 21.—DIAGRAMMATIC VIEW AND SECTION OF THE THAMES VALLEY NORTH OF HENLEY.—*H. J. Osborne White.*

a. Middle Chalk.
b. Upper Chalk.
1. Pebble Gravel on Reading outlier, 520 feet O.D.
2. Terrace Gravel. Benham's, 400 feet.
3. Terrace Gravel. White Hill, 340 feet.
4. Terrace Gravel. No Man's Hill, 315 feet.
5. Terrace Gravel. Remenham, 180 feet.
6. Rubble Drift Fans.
7. Valley Gravel and Alluvium.

certain heights (*e.g.*, at about 240, 150, 85, and 60 feet) above the Thames in that district. The gravel spreads at 150 feet—absent to the North of Henley, but well developed to the south—appeared to belong to the very marked stage in the development of the Kennet basin which the Director had found it convenient to refer to as the "Silchester" stage.

The first section visited was that shown in the well-known Chalk Rock pit near the lower lodge of Henley Park, which is described in the Geological Survey Memoir on the Cretaceous Rocks, vol. iii, p. 212. An unsuccessful search for the name fossils of the three zones here represented (*i.e.*, *Terebratulina*, *Holaster planus*, and *Micraster cor-testudinarium*) brought to light a fair number of forms more or less characteristic of the second and third, including a specimen of *Cuspidaria caudata* from the Chalk Rock, and *Micraster præcursor* from the lumpy beds above it. It was noticed that the even upper surface of the

Chalk Rock was studded in places with casts and fragments of *Pleurotomaria*, *Turbo geinitzi*, and *Rhynchonella*.

The party then proceeded northward, by a picturesque road along the bottom of a small wooded valley, up to the open surface of the chalk upland at Crockmore Farm, and thence by Fawley, to Fawley Green. Near the last-named place a good view was obtained, south and south-westward, across the sharply incised valley of the Thames and the wooded lowland of the Loddon basin, to the distant chalk hills near Basingstoke. The Director drew attention to the circuitous course of the river through the Chalk in this district—a course which carries the stream nearly twenty miles to the north of the axis of the London basin syncline, in the meridian of Fawley; and having pointed out the topographical evidences of its high antiquity, and its probable connection with certain other peculiarities in the path of the Kennet-Thames, he briefly discussed its origin. The northward curve, by Henley and Marlow, was viewed (1) as a feature arising out of a deflection of the stream from an earlier route more in accordance with the existing structure of the London Basin, and the conditions under which the abandonment of the hypothetical consequent path would have been likely to occur, and the possible date of the change, considered; and (2) as an inheritance from a course marked out when the tectonic slopes of the region were different, or less pronounced. The data were too scanty to allow of any satisfactory conclusion being arrived at, but the balance of the evidence seemed, to the speaker, to be in favour of an antecedent origin.

The walk northward was continued to the little Eocene outlier of Wood End, which consists of a few feet of yellow, iron-shot sand, with occasional seams of black flint pebbles, forming a relic of the lower (marine) part of the Reading Beds. In some shallow excavations near the middle of the outlier the sands were seen to be covered by a loamy gravel of rolled and subangular flints and white quartz pebbles, representing the so-called "Westleton Shingle."

Retracing their steps to Fawley Green the members turned eastward, down the higher slope of the valley of the Thames, to the small but strongly-marked gravel-capped terrace on which stands the cottage named Benham's on the New 1-inch Ordnance Map. The level surface of this feature is just within the 400 feet contour line, and almost exactly 300 feet above the river at its nearest point. The Director called attention to the form of the neck of ground connecting this terrace with the main mass of the upland to the west, and contrasted its moderate inclination with the steeper slopes of the valley side to the north and south. He believed that the side of the valley immediately behind the terrace still retained, in a large measure, the slope which it had acquired when the terrace itself formed part of the

bed or flood-plain of the river, while it had elsewhere assumed the steeper inclination appropriate to the existing lower base-level of the district and higher relief of the chalk upland.

A pit about 10 feet in depth at the inner, riverward, margin of the terrace showed a rather obscured section of gravel containing a large proportion of Bunter quartzite pebbles, blocks of vein-quartz, and other rocks of distant origin. A worn sarsen, measuring 18 × 14 × 12 inches, lay on the floor of the pit. The pieces of Lower Greensand chert common in many of the lower gravels near Henley seemed to be wanting here.

The descent was resumed, by the primrose and blue-bell carpeted slopes of Row Wood, to an excavation at the south-western edge of Oaken Grove, near the Marlow road, which showed a clear section, about 15 feet in depth, of Rubble Drift composed of white angular flints, with some flint, sarsen, quartzite, and other pebbles, in a compact matrix of fine chalk fragments and light-brown loam, exhibiting signs of irregular bedding. In the upper part of the section the drift had weathered into a dark, stoney loam. The Director remarked that this rubbly deposit covered the chalk over wide areas of the lower side-slopes of the Thames valley in this neighbourhood, occurring partly in the form of broad sheets, with upwardly concave surfaces, thinning out up the valley walls, partly as depressed cone- or fan-shaped masses, of convex profile, about the mouths of small lateral valleys or combes. The sheets spreading down the unbreached portions of the sides of the main valley differed in no important respect from the Rubble Drift deposits of other chalk districts, but the fans (in one of which the Oaken Grove pit had been opened) were somewhat exceptional, and their form, internal structure, and position pointed to their having been built up by rapid streams descending the short, steep-sided, and now, for the most part, waterless valleys at whose mouths they were situated. The streams referred to appeared to have been of considerable volume, and heavily charged with material derived, in a large measure, directly from the chalk. Their action had doubtless been intermittent, but the general smoothness of the surface of the fans, together with the absence of weathered zones within the rubble, rendered it improbable that formation of the fans had occupied any considerable fraction of Pleistocene time. These rubble deposits were probably of about the same (late Glacial) age as the Combe Rock sheets of the Sussex Levels, and of somewhat similar origin.

The relation of the Rubble Drift to the later river deposits in the Henley district was not absolutely clear, but as the former passed under the alluvium of the water-meadows, and as a similar chalky drift had been found beneath the gravel in, and near to, the bed of the river, in excavations for new weirs and for drainage purposes, it not improbably underlay all the deposits

which went to form the existing flood-plain of the Thames, though a certain amount of inter-digitation with, or replacement by, the lowermost beds of river gravel was only to be expected. If the inferred relation was the actual one, then the Rubble Drift dated from the epoch in which the Thames Valley attained its maximum depth, and marked the commencement of the aggrading or infilling process still in operation. So far as the Director was aware, the greatest thickness of alluvium in the bottom of this part of the valley hitherto recorded was 38 feet, which had been proved in a well at Hurley.

The party then moved eastward to Mill End, observing *en route* the gentle rise and fall of the road in its passage across three of the above-mentioned rubble fans, and the low scarp-features due to the dissection of one of the latter by the lateral cutting of the Thames and the Hambleden brook.

At Mill End the excursion crossed the river by the narrow footbridge of Hambleden Weir, and proceeded southward through the water-meadows on the Berkshire side, to tea at the Aston "Flower Pot." On the proposal of Mr. Whitaker, a warm vote of thanks was awarded the Director at the conclusion of the meal, and the party then divided—the Oxford members hastening back to Henley Station, while the remainder walked on to Remenham.

Here some minutes were devoted to the two good sections a little to the east of the church; one in the gravel of an exceptionally fine river terrace, about 80 feet above the Thames; the other in chalk at about the junction of *H. planus* and *M. cor-testudinarium* zones. Both were visited by the Association in 1899, and a note on the fossils of the latter will be found in the "Survey Memoir on the Upper Chalk," p. 216.

A short stroll southward to Henley by the river towing-path terminated a pleasant excursion.

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EXCURSION TO BUXTON AND NORTH DERBYSHIRE.

WHITSUNTIDE, MAY 21ST TO MAY 25TH, 1904.

Directors: H. ARNOLD BEMROSE, ASSISTED BY PROF. BOYD DAWKINS, H. H. HUBBERSTY, ESQ., AND H. LAPWORTH, ESQ.

Excursion Secretary: H. KIDNER.

(*Report by* THE DIRECTORS.)

On the evening of May 20th the majority of the members attending the excursion had assembled at the comfortable headquarters, the "Crescent Hotel," Buxton.

VISIT TO DERWENT VALLEY WATER WORKS. MAY 21ST, 1904.

By the kind permission of the Derwent Valley Water Board members of the Association were enabled to pay a visit to the Derwent Valley Water Works, which are now in progress for the supply of water to the towns of Leicester, Derby, Nottingham, and Sheffield.

The members arrived at Bamford Station at 10.15 a.m., whence they were conducted to the Board's railway connecting the Midland Railway at Bamford with the Water Works. At the Board's offices—where this line commences—a special train had been provided for conveying the members to the Water Works.

During the journey the thinning-out of the "Lower Kinder Scout Grit" on Bamford Edge was noticed, also the Sheffield Tunnel Works, the local landslips, and various other items of interest.

The members proceeded first to the "Howden" Dam site, where excavations are being carried out for the foundations of the "Howden" Dam. This is the higher of the two dams which are to be constructed in the Derwent Valley. The trench has been taken down to a depth of about 80 ft. in the Yoredale Shales Formation of the Carboniferous System, exposing a huge fold or wrinkle which extends from the ground surface to the bottom of the trench. The following sketch—reproduced from a photograph—shows the manner in which the beds have been folded, faulted, and packed.

Practically the whole base of the central portion of the dam will rest on the foundation shown in the sketch, but at the north side of the excavation a narrow trench has been sunk below this level extending to such a depth that all water percolating through

the disturbed ground will be intercepted after this narrow trench has been filled in with concrete.

Three theories have been advanced as to the formation of this wrinkle, which forms one of many in the Derwent Valley: (1) That they assumed their present form during the "Pennine" movement; (2) That they originated during the "Pennine" movement, and have been augmented by subsequent movement;

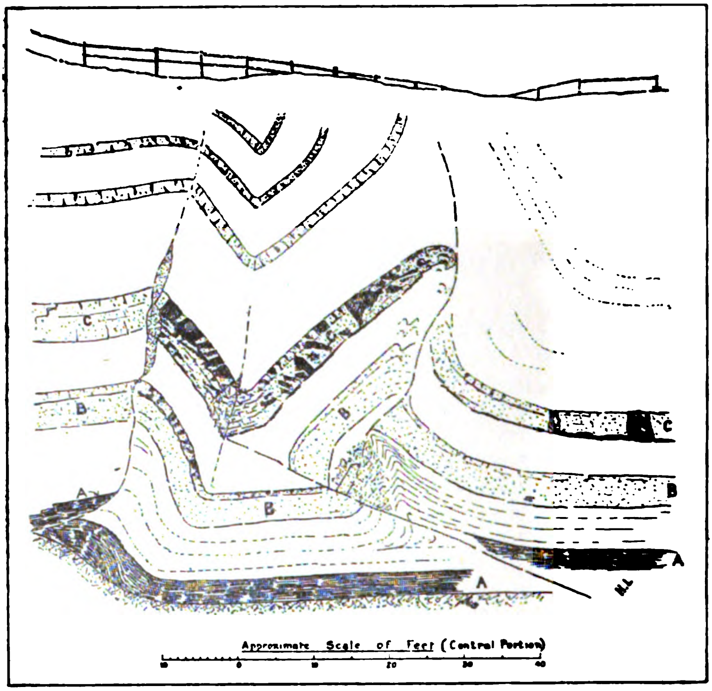

FIG. 22.—CONTORTED BEDS IN THE DERWENT VALLEY.

a.—Is a distinctive bed of carbonaceous black shales.
b. and c—Are two separate sandstone beds, each about 4 ft. thick.

(3) That they are of comparatively recent date. Prof. Boyd Dawkins pointed out that the evidence in these trenches cut across the bottom of the valley of the Derwent indicated that the faulting and crumpling of the shales and thin sandstones were due not to the ordinary faults and folds, but to a "creep" similar to that in deep mines, caused by the relaxation of pressure brought about by the removal of rock during the excavation of the valley by the stream, while the pressure remained as before in the hills on each side. He found that this was the rule rather

than the exception in all valleys cut deeply into Yoredales and Millstone Grits. In all cases the creep extends to no great depth, and the rocks are undisturbed below.

These wrinkles are characteristic of the Derwent Valley, and appear to be most prominent in the bottom of the valley. Their general direction is from north to south, or from north-north-west to south-south-east. It might be mentioned here incidentally that on the western side of the Kinder Scout anticline, where a more rapid change of dip has taken place from the level strata of Kinder Scout itself towards the steeply inclined beds to the westward, a similar set of north to south wrinkles occurs, but they show greater disturbance, and more often pass into faults of considerable displacement. A few cross folds from east to west can be observed in the Derwent Valley, but they do not reach the proportions of those running from north to south. It is possible that these are the result of the small "Pendle" movement which Prof. Hull believes to have taken place slightly before the great "Pennine" movement.

Leaving the Howden Dam the party proceeded to the "Derwent" (or lower) Dam. Here the wrinkling and faulting has been more extensive, but the individual wrinkles are not of such magnitude as the "Howden" fold, and considerable cross faulting has taken place. Unlike the shales of the Howden trench the "Yoredales" at Derwent Dam are highly fossiliferous in certain beds. Mr. Stobbs, F.G.S., has identified the following species:

Pterinopecten papyraceus.	*Glyphioceras reticulatum.*
Orthoceras pygmæum.	*Dimorphoceras gilbertsoni.*
Posidoniella lævis.	*Calamites.*
" sp. (? new)	*Rhizodus ?*
Pleuronautilus, sp.	*Lingula ?*
Glyphioceras diadema.	

This fauna appears to conform to that of the typical "Pendle-side" strata of Messrs. Hind and Howe.

An examination was made of a collection of fossils which were obtained from the trench and exhibited by the Resident Engineer, Mr. M. G. Weekes.

At this stage, Mr. Sandeman and Mr. Winser, the Engineer and Deputy Engineer, pointed out and explained the cableways and other items of engineering interest which were to be seen.

Leaving the Derwent Dam the party proceeded to Ashopton, where lunch was obtained, after which members proceeded to Bamford, where they left the train for brakes. A drive followed of about four miles to the Bole Hill Quarries. Here stone is being obtained for the building of the dams. The party dismounted at "The Surprise," which lies immediately above the Quarries and commands an extensive view of the surrounding

country. Here, Professor Boyd Dawkins gave a most interesting address on the geology of the district, explaining how the great north and south anticlinal arch, composed of Carboniferous Limestone, Yoredale and Millstone Grit, which forms the *massif* of the Pennine Chain, had been carved out by the agencies of denudation. Mr. Lapworth followed, giving a *resumé* of Dr. Hind's theories as to the derivation of the grits.

The Quarries are in the "Rivelin Grit" Bed of the "Millstone Grit" Series. The rock contains a large proportion of felspar and some mica; it appears to have been derived from a granitic area. Petrological experts who were present were of the opinion that the material is not of very distant origin. After a collection of hand specimens and an examination of the working arrangements of the Quarries had been made, the party proceeded to the "Maynard Arms," where tea was served, and left Grindleford at 5.25 p.m. for Buxton.

MAY 22ND, 1904.

Some of the members visited the Wye valley near Miller's Dale, and admired the magnificent Tor in Chee Dale, and a short distance above it up the river the narrow gorge in the lower parts of the valley. They returned to Wormhill springs, which issue from above the lava, proceeded by Wormhill to Great Rocks Dale, and examined and discussed the evidence for one or two faults which have let down a small portion of the Toadstone, so that it abuts against the limestone. They noticed a decided change of feature, from a narrow rocky dale shut in by limestone cliffs, to a grass-covered, gently-sloping valley in the softer lava. They then walked over an intrusive sill to Waterswallows, where they found some erratics of igneous rocks foreign to the county, and visited numerous swallow-holes, down some of which they saw water disappear.

MAY 23RD, 1904.

Directors: PROF. BOYD DAWKINS, H. A. HUBBERSTY, H. ARNOLD BEMROSE.

Report by H. ARNOLD BEMROSE.

The party walked to Sherbrook and examined section of vesicular lava on the roadside, thence by fields to Staden Low to see lava faulted against limestone; evidences for the fault were pointed out on the west and east sides of the Low. From the Low fine views of the surrounding country were seen. On the west side Mr. Hubbersty pointed out the interesting features in the landscape, and Mr. Bemrose gave a brief description of the geology and showed that the view embraced the north-west portion of the mountain limestone region in the foreground and the Yoredales and grits in the distance, to the north were seen the Peak and Mam Tor near Castleton, and to the east the main

mass of mountain limestone country. The members proceeded by Foxlow Farm to Harper Hill Quarry, where Prof. Boyd Dawkins met them.

At Harper Hill the members were shown the Limestone Quarries of the Buxton Lime Firms Company, Limited. The beds of limestone are thrown up and separated by vertical faults as shown by the plan and section (Fig. 23). From which

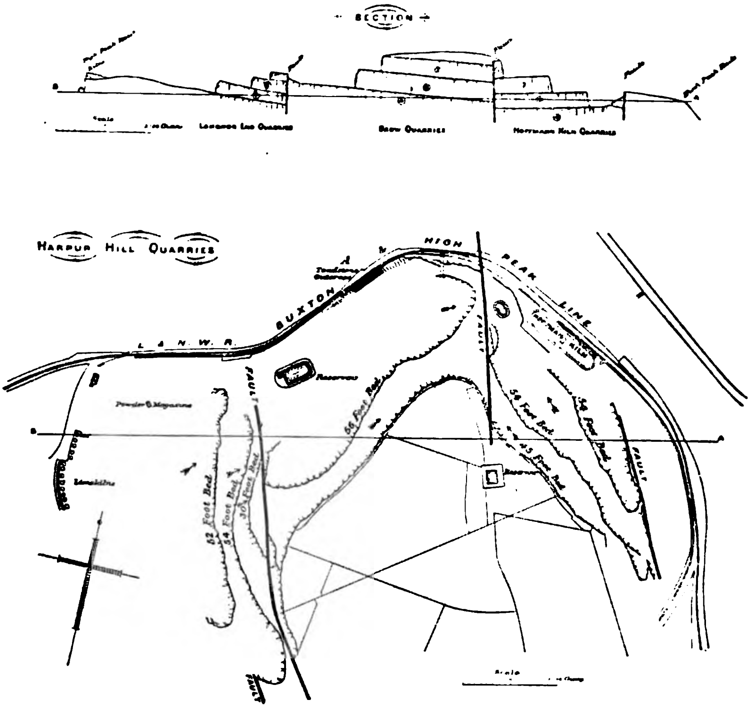

FIG. 23.—PLAN AND SECTION, HARPER HILL QUARRIES.

it will be seen that the beds are not only altered in "dip," but are also very much displaced.

The quality, or texture, and the colour of the stone in the several beds were shown to vary considerably, and it was difficult to trace, definitely, whether the beds Nos. 2 and 3, in the Hoffman Quarry, or northern portion of the section, are the same as Nos. 2 and 3 in the Brow Quarries, or central portion, although there is a great similarity in the stone.

The beds in the Longnor End Quarries, on the south, Nos. 5, 6 and 7, do not correspond with any of the preceding: but resemble those subsequently seen at the Grin Quarries. They are probably below the Toadstone, as a similar bed to No. 5 is worked by the Lime Firms Company at Millers Dale, under the Toadstone.

A bed of Toadstone was pointed out under No. 4 bed in the centre portion, or Brow Quarries, at the point marked A on the plan, adjoining the High Peak Railway; but it has not been found in any other portion of this Quarry or at Grin Works.

The beds of clay—part blue, part yellow—which separate Nos. 2 and 3 limestone beds, with the fossils underneath, were examined. The analysis of each clay is as follows:

	Blue Clay.	Yellow Clay.
Silica	38.75	36.5
Alumina	35.90	32.8
Iron Oxide	.25	2.9
Lime and Magnesia	3.75	4.2
Loss on Calcination	20.23	22.7

The fault Breccia was particularly interesting, many portions of the rock fragments being dolomitised, and covered with a considerable thickness of crystals. (The clay with which some faults are filled being apparently of a similar character to that in which the Pliocene remains were found in the Dove Holes cavern, near Buxton, the working at a lower level might possibly produce corresponding evidence.) Nodules of lead ore, of copper ore, and of "cawk," or barytes, have been at times found in it; but unfortunately no regular and careful examination has been made during the quarrying process.

After leaving the Quarry the party proceeded to the site of the New Buxton Waterworks, near Ladmanlow, where Prof. Boyd Dawkins pointed out the fault between the Mountain Limestone and Yoredale Shales, and explained the method of construction of the proposed reservoir. Several swallows in the limestone, down which water from the shales was disappearing, were examined. In some of these were Yoredale and Millstone Grit pebbles. Grin Low Quarry was next visited. Prof. Boyd Dawkins pointed out several hollows or caverns in the limestone filled with more or less weathered pebbles of Millstone Grit, and gave a most delightful account of his find at Doveholes of Pliocene bones, and suggested that such a hollow in which he stood was just the kind of place for geologists to search for Pliocene mammalia.

Pooles Cavern was visited, and the party proceeded to the Buxton Museum, where the Professor described the portion of the Doveholes Pliocene bones, which were in a glass case.

MAY 24TH, 1904.

Director: H. ARNOLD BEMROSE.

The party proceeded to Ambergate by train and walked to Crich Village. By the kindness of the Butterley Company they visited Hill's Quarry and the adjoining old quarry, in which very fine specimens of Boulder Clay were seen. The clay is a tough reddish or bluish deposit with streaks or patches of sand, sandy gravel, or sandy clay. It is thickly studded with boulders, many of which were seen to be finely polished or grooved. The boulders examined included limestone, gritstone, sandstone, toadstone, Bunter pebbles, and various foreign greenstones and granites. The Director pointed out a boulder of curious rock of a pinkish felspathic base studded with green specks. It was thought to be spherulitic, but none of the party could name it. A patch of "calcrete," consisting of boulders and pebbles of sandstone and Bunter pebbles cemented together, and suggestive of glacial action, was seen. Portions of the striated floor of limestone from which the clay had been lately removed were examined.

Attention was called to a "wayboard" or bed of clay in the limestone. Such beds are common in the limestone. The surface of limestone under these clays and also under the lava streams is often worn into a pothole-like structure. A discussion arose as to whether the weathering took place subsequent to the deposition of the clay or whether the weathered surface denoted some erosion of this limestone before the clay was deposited. In support of the latter view it was pointed out by one of the members that whilst the surface of the limestone below the clay contained these irregularly shaped hollows the surface of the limestone above the clay was an ordinary bedding plane free from such hollows.

Part of an old cavern was seen in section. The hollow was filled with clay and decomposed limestone, and portions of two stalactites were found in it.

Before leaving the Quarry the President thanked Mr. Bemrose and Mr. Coke for arranging and carrying out such an enjoyable excursion in Derbyshire.

The party walked back to Ambergate through Fritchley. Some members returned to London and the remainder to Buxton.

MAY 25TH, 1904.

Director: H. ARNOLD BEMROSE.

The party left Buxton by train for Mousal Dale Station, and visited the spar mine near the station. The calc-spar containing traces of galena and barytes fills a rake vein about 8 feet in width. The members walked along the level for about 600 yards, and saw the underground workings. Mr. Money Kent

collected specimens of the curious fungi growing on the timber in the "level." Many members led by Mr. Froggatt penetrated the recesses of the mine, and by means of ladders and stempals and sloping paths, visited part of the old lead mine, and the various levels at which the spar is worked, and finally emerged to daylight at a height of 500 feet above the place of entry. A hearty vote of thanks to Mr. Froggatt for his kindness was proposed by Mr. Whitaker. A descent was made into the dale, and on the way up to the Headstones a small limestone quarry was visited. The rocks consisted of thin beds of black limestone with partings of black chert. At the Headstones the Director pointed out the magnificent views of the Wye valley and the surrounding country, and led the visitors down into the rabbit warren. For the first time during the excursion the rain descended in a fine drizzle.

On the way, the upper lava in the bank of the river was pointed out, and two small quarries in tufa were examined. The two lava flows, separated by about 150 feet of limestone, were seen on the slopes of Fin Cop. At New Bridge the upper lava stream below the thin cherty limestones was seen. The Director drew attention to the vesicular and slaggy lava, and to the hard spheroidal coarse-grained ophitic dolerite below it, and said that he considered it was a similar case to that in Tideswell Dale, where a sill, or intrusive rock, had pushed its way up and proceeded along a plane of weakness below and up to the lower part of the lava flow. From here the party drove through Ashford to Bakewell, and visited the Holme Bank chert quarries. Large blocks of siliceous rock are obtained and sent to the potteries for grinding purposes. Mr. Long, the manager, met the members and conducted them through some of the underground workings. The method of mining the rocks by undercutting was explained. The siliceous bed is about 4 feet thick, and is unlike the chert often found in the limestones. Some beds are traversed by threads or veins of silica. Some geodes were found with crystalline quartz, and here and there were chalcedony-like masses.

The Director on being asked about the microscopic structure of the siliceous rock said that the pieces he had examined consisted of a microcrystalline quartz mosaic often passing into a cryptocrystalline structure, which contains small patches of the former; and that the threads of silica which traverse the rock are composed of a mosaic of clear quartz grains which have no crystalline outline, and are not elongated like those in the quartz rock at Bousall and Castleton. A vote of thanks to Mr. Long terminated the geological part of the excursion. After tea at Bakewell the members returned to London, Derby, and Birmingham.

Note.—The great interest in underground fungi is that they

are generally in an abnormal state, and therefore most difficult to determine. Three kinds were found in the Spar mine:

1. *Ozonium auriconium.*—This is the brown old-man's-beard-like material in the mycelium of a fungus undetermined because it has never been known to fructify. The beautiful white silky material hanging down somewhat similarly is probably a young form of the same fungus.

2. *Coprinus atramentarius.*

3. *Polyporus.*—Too abnormal to be named specifically.

The above have been verified by Mr. V. H. Buckman, of the British Museum (Cryptogams).

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No. 5. 1900 DEELEY, R. M.—"Fine Section of a Boulder Clay at Crich." *Geol. Mag.*, Oct., 1900, pp. 476, 477.

ORDINARY MEETING.

FRIDAY, MARCH 4TH, 1904.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association: T. R. Croger, Ruthven Finlayson, William D. Shuard.

The President referred in sympathetic terms to the loss sustained by the Association by the death of its former President, Lieut.-General C. A. McMahon.

Dr. C. Gilbert Cullis then exhibited, by means of the lantern, about fifty beautiful photographs, comprising the first two series issued to subscribers by the British Association Geological Photographs Committee. After a brief explanation of the manner in which the photographs are issued, Dr. Cullis proceeded to point out in a lucid manner the principal features exhibited by each of the slides.

ORDINARY MEETING.

FRIDAY, APRIL 8TH, 1904.

DR. A. SMITH WOODWARD, F.R.S., President, in the Chair.

J. F. Colyer was elected a member of the Association.

Mr. George Barrow then delivered a lecture on "The Metamorphism of Sediments," his remarks being illustrated by the projection of a series of microscopic slides on the screen.

ORDINARY MEETING.

FRIDAY, MAY 6TH, 1904.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association: Miss Grace M. Bauer, Rev. Charles T. Pratt, M.A., Arthur Beeby Thompson, A.M.I.Mech.E.

Mr. H. Arnold Bemrose then delivered a lecture on "The Geology of Buxton," with special reference to the Whitsuntide Excursion, his remarks being illustrated by lantern slides.

ORDINARY MEETING.

FRIDAY, JUNE 3RD, 1904.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association: John Cadman, M.Sc., Claude C. Chidell, M.B., Cecil Duncan, J. L. Foucar, Percy E. Spielman.

Mr. W. J. Lewis Abbott then delivered a lecture on "The Geology and Prehistoric Anthropology of the Hastings District," with special reference to the excursion on June 11th, illustrated by lantern slides.

Mr. G. E. Dibley exhibited plates of *Marsupites*, nipple headed form of *Bourgueticrinus*, and *Echinocorys pyramidatus* from Russell Hill, Purley, also a tooth of *Ptychodus Oweni* from the *Holaster sub-globosus*-zone at Holborough, Rochester.

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FOUNDED 1858.

THE OBJECT of the Association is to facilitate the study of Geology and its allied Sciences.

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FIELD EXCURSIONS and Visits to Museums and other places of Geological interest are made at various dates, principally between March and August.

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OF THE

Geologists' Association.

EDITED BY

J. ALLEN HOWE, B.Sc., F.G.S.

(*Authors alone are responsible for the statements in their respective Papers.*)

Contents.

* *Advance Copies of this Paper were issued in July to Members taking part in the Long Excursion.*

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By Geo. F. Harris, F.G.S., and H. W. Burrows, A.R.I.B.A.

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(*Continued on page 3 of the Cover.*)

NOTES ON THE GEOLOGY AND FOSSILS OF THE LUDLOW DISTRICT.

BY A. SMITH WOODWARD, LL.D., F.R.S., President.

(A few advance copies issued to members in July, 1904.)

UNDER the presidency of a palæontologist it seems appropriate that the Geologists' Association should devote its Long Excursion this year to the study of fossils in the field. It becomes more and more evident, as researches progress, that the past history of life on the earth can only be satisfactorily deciphered when the exact stratigraphical position of each fossil has been determined by careful collecting. The variations of an organism in time and space, and its successive migrations, can only be ascertained by more detailed field-work and more precise labelling than has hitherto been customary among palæontologists. It is therefore necessary to follow the lead of Lapworth, Buckman, Rowe, Wheelton Hind, Miss Elles, Miss Wood, and others who are inaugurating a new era in the study of British fossils by a most exact and exhaustive method of collecting. The Association, indeed, cannot do better at the present time than attempt to arouse renewed interest in a classic district, which has been much neglected by geologists during recent years, and has scarcely been examined in any respect from the modern standpoint.

The classic ground we have chosen to visit is the old country of the Silures, where Murchison originally worked out the details of his Silurian System. Much of it has never been visited by the Association before, and thirty-two years have now elapsed since Ludlow was the centre of one of our excursions. At the present time, in fact, the district is probably much more familiar to archæologists than to geologists. The generation of local geologists whom Murchison inspired half a century ago, has now passed away, and this band of pioneers has fewer successors than might be expected in a country so replete with interest.

Ludlow itself is situated chiefly on the Lower Old Red Sandstone, but also partly on the Upper Silurian Rocks, which crop out in regular succession beneath it. The strata are more or less disturbed by faults connected with a great line of dislocation which extends in a N.E. and S.W. direction from Lilleshall in the north to Kington in the south (see Lapworth and Watts, 1894). The Old Red forms a gently undulating pastoral country, while the alternating layers of shaly mudstone and hard limestone in the Upper Silurian produce steeply scarped ridges, which are covered for the most part with plantations, and are separated from each other by rich arable land in the hollows.

The general succession of the rocks, long ago established by Murchison and his fellow-geologists on the spot, and little modified by subsequent observers, is as follows:

OLD RED SANDSTONE.	Upper Sandstones, with *Bothriolepis*, *Holoptychius*, *Sauripterus*, &c.	
	Lower Sandstones, Marls, and Cornstones, with *Cephalaspis*, *Pteraspis*, &c.	
SILURIAN.	Ludlow Group.	Tilestones.
		Downton Sandstone.
		Upper Ludlow.
		Aymestry Limestone.
		Lower Ludlow.
	Wenlock Group.	Wenlock Limestone.
		Wenlock Shales.
		Woolhope Limestone.
	Llandovery Group.	Tarannon or Woolhope Shales.
		Upper Llandovery and May Hill Sandstone.
		Lower Llandovery.

These strata are a conformable series, and the Upper Old Red Sandstone passes gradually into the Carboniferous Limestone above; but there is a marked unconformity at the base between the Llandovery group and the underlying Ordovician rocks, as is well seen between the Longmynd and Wenlock Edge (Fig. 9).

DOLERITE AND CARBONIFEROUS SERIES.

Before considering these Old Red Sandstone and Silurian formations more in detail, however, it is interesting to refer to the flat-topped Clee Hills, which rise to a height of 1,530 and 1,750 feet above sea-level five or six miles to the eastward of Ludlow. It happens that in this locality at some post-Carboniferous date (probably Permian) there was a volcanic outburst, by which a thick sheet of dolerite was spread over the Coal Measures. The comparatively soft strata of shales and sandstones, with their included seams of coal, were thus preserved from denudation by a capping of intensely hard rock; and whereas the Western Coalfield has been denuded off the Ludlow District, and indeed off the whole of the country between Shropshire and the South Wales Coalfield, a small outlier remains intact beneath the Clee Hill volcanic flow, and rises above the level of the adjoining land. The dolerite itself was studied by the late Mr. Allport, and described in his well-known paper in which he proved for the first time the essential identity of the lava of all geological ages. It is a coarse rock remarkable for the freshness of its constituents, even exhibiting much olivine with very little trace of serpentinisation. It is extensively worked for road-metal, and its columnar structure is often well seen in the quarry face. It is locally known as *dhu stone*, the name being

supposed to have been derived from a Celtic word meaning black.

As shown by Murchison's section (Fig. 24) the Coal Measures of the Clee are arranged in a slight syncline, and if the gradual slope of the hills be descended to the north-east the Lower Carboniferous strata can be observed dipping at a very high angle. The fine section of the Carboniferous Limestone Series in the Oreton quarries is especially interesting, and shows a gradual passage downwards from the typical marine limestones to the yellow and probably lacustrine sandstones of the Upper Old Red. The Oreton section does not appear to have been studied for more than forty years, when Morris and Roberts presented the accompanying sketch of it (Fig. 25) to the Geological Society. It will be observed that there are no massive beds, but only a

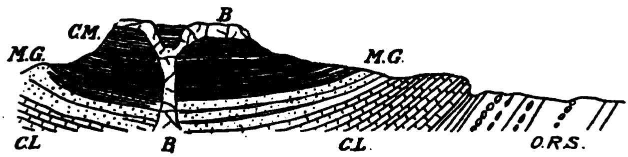

FIG. 24.—SECTION ACROSS THE CORNBROOK COAL BASIN OF THE CLEE HILLS.—*Murchison.*

C.M. Coal Measures. M.G. Millstone Grit. C.L. Carboniferous Limestone. O.R.S. Upper Old Red Sandstone. B. Dolerite.

succession of comparatively thin layers of oolitic or shelly limestone, clay, and even sandy rock. Brachiopods are abundant in the limestone; and one layer consists of the scattered remains of crinoids mingled with Polyzoa. The most interesting fossils, however, are the teeth and fin-spines of pelagic sharks, which are not uncommon in certain beds. Most of the species are peculiar to Oreton, though they belong to widely distributed genera, and the list given by Morris and Roberts in 1862 needs much revision. The fine teeth of *Orodus ramosus* and *Sandalodus morrisi*, and the fin-spines named *Ctenacanthus major* and *C. sulcatus*, are identical with fossil teeth and spines occurring in the Black Rock at Clifton, Bristol; but so far as I have observed, there is no similarity between the Oreton fish-fauna and that met with in the bone-bed of the Lower Limestone Shales at Clifton. This is a fact of peculiar interest to those who are studying the life-zones of the Lower Carboniferous Series.

UPPER OLD RED SANDSTONE.

The Old Red Sandstone of the "Welsh Lake" (as it has been termed by Sir Archibald Geikie) needs much more detailed investigation than has hitherto been bestowed upon it; but whether

it consists of one conformable series of deposits, as commonly supposed, or whether it exhibits unconformities at any horizons, the fossil fishes contained in it represent two very distinct faunas. Where the strata are clearly the uppermost of the Old Red Series, like the yellow sandstones of Farlow which immediately underlie the Carboniferous Limestone near Oreton (Fig. 25), the fish-fauna corresponds with that which is definitely known to characterise the Upper Old Red Sandstone of Scotland. This fauna was first noticed half a century ago in a small quarry in the yellow sandstone at Farlow, which was temporarily worked for the rebuilding of the church. Numerous fragmentary fish-remains, in fact, were collected here by Mr. T. Baxter, Mr. G. E. Roberts, and others; and among them were several fine examples of a peculiar species of *Bothriolepis*, which Sir Philip Egerton described under the name of *Pterichthys macrocephalus*. As first recognised by Dr. Traquair, this fish is shown to be a typical Upper Old Red *Bothriolepis* by

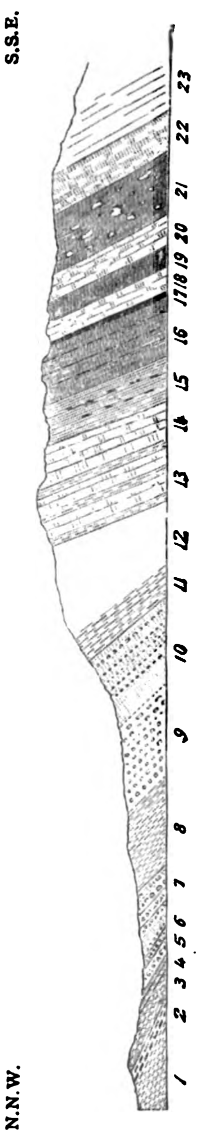

FIG. 25.—SECTION FROM ORETON QUARRIES TO FARLOW.—*Morris and Roberts.*

1–3. Upper Old Red Sandstone, namely (1) Fissile Sandstone, (2) Cornstones, and (3) Red Sandstone; 4–13. Passage Beds, namely (4) Laminated Yellow Sand, (5) Pebbles in Yellow Sand, (6) Sands and Breccia, (7) Yellow Pebble-beds, (8) Yellow Sandstones with *Bothriolepis*, (9) Pebble-beds, (10) Sands and Pebbles, (11) Laminated Yellow Sand, (12) Unknown ground, 50 feet, (13) Yellow Sandstone with Limestone-concretions and Veins of Calc-spar; 14–23. Lower Carboniferous Limestone Series, namely (14) Grey Oolite with fish-teeth, 3 ft. 6 in., (15) Grey Oolite or Clee Hill Marble and Sandrock, 6 ft. 6 in., (16) Soft Sandy Rock and Clays, 4 ft. 2 in., (17) Black Clay, 4 in., (18) Grey Shelly Limestone, 1 ft., (19) Brown Clays, 2 ft., (20) Grey Crinoidal Limestone with Polyzoa, 4 ft. 6 in., (21) Dark-grey Clays with Limestone-concretions, 6 ft., (22) Sandy Beds with thin layers of Limestone, 3 ft., (23) Bands of Sandy Limestone with concretions of Argillaceous Limestone.

the characters of its body-plates and arms and by the absence of a scaly tail. With it are scales and teeth which were originally mistaken for those of *Holoptychius*, but they seem to belong to an equally typical Upper Old Red genus *Sauripterus*, which occurs in Scotland and North America (Catskill Group). Scales of undoubted *Holoptychius* have been found at Portishead, near Bristol, and at Tortworth, Gloucestershire, where

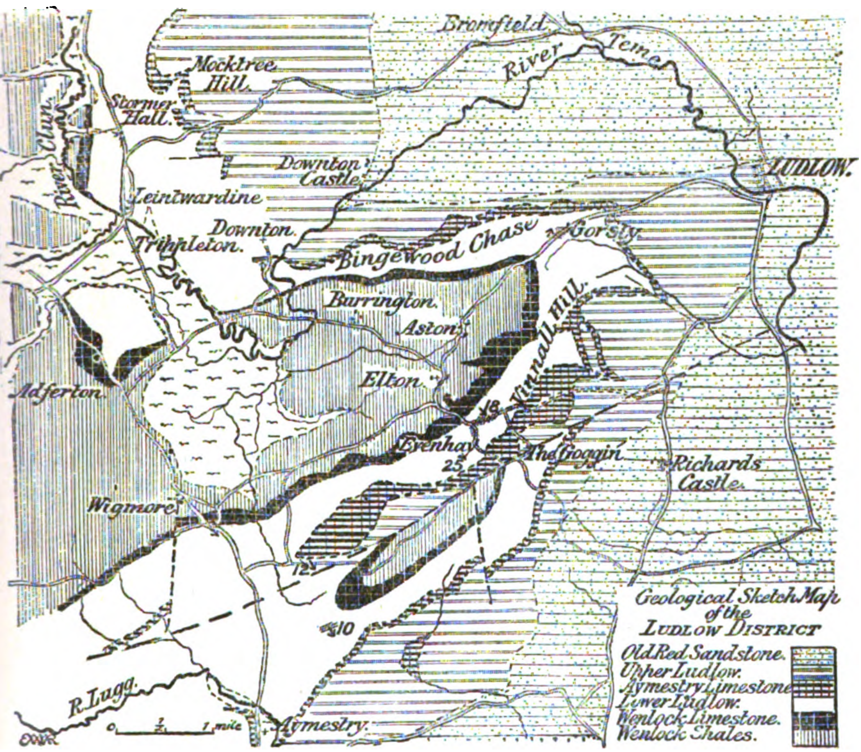

FIG. 26.—MAP OF THE NEIGHBOURHOOD OF LUDLOW.—*Miss Wood.*

there is stratigraphical evidence of the high place in the Old Red series occupied by the sandstone which contains these fossils.

It may, in fact, be stated that *Holoptychius* and *Sauripterus* (or Crossopterygian genera of equivalent rank) with *Bothriolepis* and *Asterolepis* characterise the Upper Old Red Sandstone or Upper Devonian wherever it occurs—in Britain, Belgium, Germany, Russia, Spitzbergen, Greenland, Canada, and the Catskills of New York. All assertions to the contrary are based on the

wrong interpretation of the fragments, by which alone the fishes are so frequently represented.

Below the Upper Old Red Sandstone in the north of Scotland ("Lake Orcadie") there is a series of rocks—the Middle Devonian of Murchison—yielding another fish-fauna, which is characterised by *Dipterus*, *Osteolepis*, *Coccosteus* and *Pterichthys*, and has not yet been found in the Welsh area. It is very desirable that a special search should be made for this group of genera in the sandstones immediately beneath the Upper Old Red in the district now being described.

Lower Old Red Sandstone.

The red sandstones, marls, and included nodular limestones (locally known as *cornstones*), which are definitely determined at many points to constitute the lower part of the Old Red series formed in the "Welsh Lake," contain numerous fish-remains of the genera *Pteraspis*, *Cephalaspis*, and *Phlyctænaspis*. This is the typical Lower Devonian Fish-Fauna, and occurs with slight variations in regions so remote from each other as Cornwall, Southern Scotland (especially Forfarshire), Galicia, Spitzbergen, New Brunswick, and Newfoundland. The rocks containing the fish-remains, indeed, are almost identical in the Welsh area, Spitzbergen, and Newfoundland; and if specimens from these different localities were mixed it would be difficult to separate them correctly. As a rule, the fossils are very fragmentary, and bear evidence of drifting by currents. They are sorted into shapes and sizes as the result of this transportation, and when one specimen occurs it is not uncommon to find a small collection of the same kind grouped together. Fragments of *Stylonurus* and other Eurypterids are occasionally discovered with the fish-remains.

The more massive beds of the Lower Old Red Sandstone are sometimes worked in quarries, but the Cornstones are rarely exposed except in temporary excavations in fields. The satisfactory collecting of fossils from these rocks can therefore only be undertaken by residents who will make a regular search and take advantage of each opportunity.

Passage Beds and Upper Ludlow.

Wherever the base of the Lower Old Red Sandstone can be studied in the area of the "Welsh Lake," it is found to pass gradually downwards into the marine though shallow-water sandstones of the Upper Silurian. The lacustrine conditions of the Devonian period in this region thus began by gradations as

insensible as those already mentioned, by which the lake was again swamped by the sea at the dawn of Carboniferous times. The Passage Beds in question vary in different places in constitution and thickness, but they all show the mingling of truly

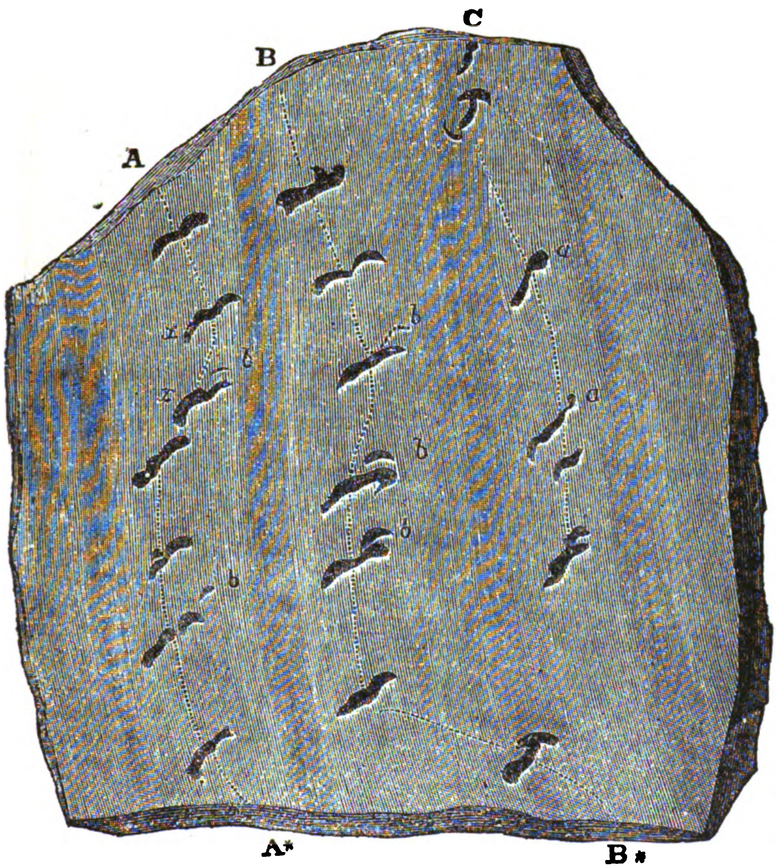

FIG. 27.—THREE TRACKS (A, B, C) OF UNDETERMINED ANIMALS DISCOVERED BY R. W. BANKS IN THE DOWNTON SANDSTONE, KINGTON; ABOUT ONE-QUARTER NATURAL SIZE.—*After J. W. Salter.*

marine fossils such as *Lingula* with the Fishes and Eurypterids, which must have been able to live either in the open sea or in lakes. In the micaceous flagstones of this series on the borders of Brecon, indeed, there are lenticular patches of marine shells identical with those of the Upper Ludlow. The massive

FIG. 28.—TRACKS OF UNDETERMINED ANIMALS DISCOVERED BY R. W. BANKS IN THE DOWNTON SANDSTONE, KINGTON; ABOUT ONE-THIRD NATURAL SIZE.—*After J. W. Salter.*

Downton Sandstone, however, and the Tilestones in the neighbourhood of Ludlow and Kington, as also the corresponding Passage Beds exposed in the fine railway-section at Ledbury, are marked by an easily recognisable Fish-fauna, which extends as far downwards at least as the Upper Ludlow Bone-bed. *Cephalaspis* still occurs, but *Eukeraspis* and *Auchenaspis* are more common Cephalaspidians, and *Didymaspis* is an allied genus; while *Pteraspis* is replaced by the simpler shield named *Cyathaspis*. There are also fin-spines like those of sharks (*Onchus*). A nearly similar fauna is found on the same horizon in limestones in the Isle of Oesel, Baltic Sea, and there are indications of it also in

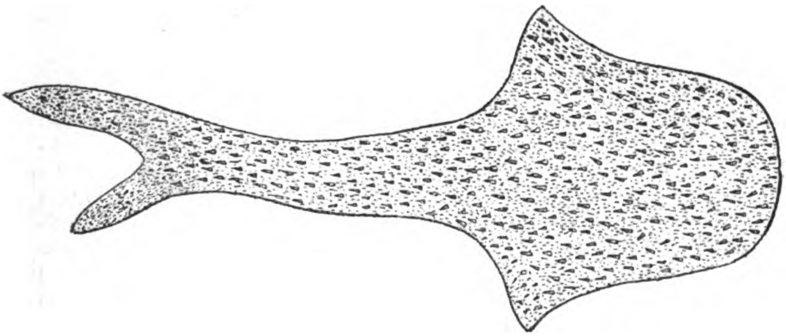

FIG. 29.—RESTORED OUTLINE OF *Lanarkia spinosa* (ALLIED TO *Thelodus*) IN THE POSITION IN WHICH IT OCCURS AS A FOSSIL, NAMELY, VERTICALLY COMPRESSED IN FRONT, BUT THE TAIL TWISTED ROUND SO AS TO APPEAR IN PROFILE.—UPPER SILURIAN, LANARKSHIRE. NATURAL SIZE.—*After Traquair.*

North America. With the fish-remains are numerous fragments of Eurypterids, and also traces of land-plants.

Sporadic evidence of the appearance of this uppermost Silurian fauna is known as far down in the series as the Lower Ludlow of Leintwardine and the Wenlock Limestone of the Isle of Gothland in the Baltic Sea; but, as already mentioned, it is generally restricted to the Upper Ludlow and Passage Beds. Its beginning is curiously marked over an area of at least a thousand square miles by the Ludlow Bone-bed, which is a layer of small and even minute fish-fragments mingled with comminuted remains of other animals which have been washed together. Notwithstanding its great extent this bone-bed is rarely more than three or four inches in thickness. Unfortunately, however, the evidence of drifting currents which is seen here and in the overlying Old Red Sandstone, also pervades the whole of the

Upper Ludlow and Passage Beds in the area now under consideration. Many of the sandstones and mudstones must indeed have been deposited quite at the shore-line as shown by the occasional preservation of the tracks of animals (Figs. 27, 28). The fishes, crustaceans, and plants are therefore known for the most part only by unsatisfactory fragments, and it is necessary to turn to the equivalent rocks of other regions for better specimens.

Some such fossils have already been found in the Passage Beds and Upper Silurian Flagstones of Lanarkshire in Scotland; and here there is a clue to the nature of the fish-like organisms whose disintegrated armour forms perhaps the greater part of the bone-bed. The minute square or rhomboidal shining tubercles, which Agassiz named *Thelodus* and which most closely resemble the skin-covering of a shark, are arranged on the Lanarkshire flagstones in small patches shaped like the accompanying Fig. 6. It is therefore evident that they covered an animal of the same form as *Cephalaspis*, with a broad horseshoe-shaped head-region and a slender tail-region, terminating in a heterocercal tail. So far as the armour is concerned, in fact, they might readily have been changed either into a Pteraspidian or into a Cephalaspidian by the fusion of the skin tubercles in different ways into plates. As some intermediate stages have been found, there can be no doubt that these Coelolepidæ (to use Pander's term) are the most primitive armoured members of the great group of lowly vertebrata to which *Pteraspis* and *Cephalaspis* belong.

As all the known geological formations older than the Upper Ludlow are marine, and as they contain no undoubted traces of fish-like organisms except the rare shields of *Cyathaspis* already mentioned, the fossils of the mudstones, flagstones, and sandstones now under consideration are of the deepest interest. They reveal backboned animals for the first time in the history of the earth, and these are shaped like fishes although they belong to the lowest conceivable grade (Ostracodermi), being apparently destitute both of ordinary fish-jaws and of paired fins. We know nothing of their ancestors probably because they lacked hard armour. With the Ostracoderms there appear for the first time traces of life on the land. A small scorpion (*Palæophonus*) has been found both in the Ludlow rocks of Lanarkshire and the Upper Silurian of Gothland; and, although this animal may have lived in water, it is remarkably similar to a modern land scorpion. There is also not much doubt that most of the associated fragmentary vegetable remains belong to land plants (see p. 458). In short, the Upper Ludlow and Passage Beds deserve to be continually watched wherever they are exposed and excavated; and it is not unlikely that even so hasty an examination as the Geologists' Association will be able to make of them may result in the discovery of fossils of real value.

FIG. 30.—SECTION ACROSS THE LUDLOW SERIES.—*Murchison.*

O.R.S. Lower Old Red Sandstone. U.L. Upper Ludlow. A.L. Aymestry Limestone. L.L.Sh. Lower Ludlow Shale. W.L. Wenlock Limestone. W.Sh. Wenlock Shale.

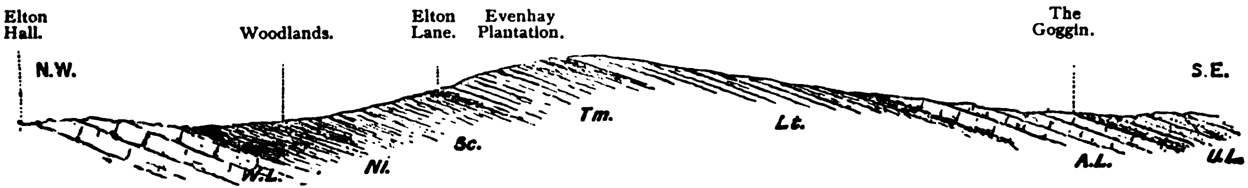

FIG. 31.—SECTION FROM ELTON HALL TO THE GOGGIN ACROSS ELTON LANE.—*Miss Wood.*

W.L. Wenlock Limestone. Ni. to Lt. Lower Ludlow zones of *Monograptus nilssoni*, *M. scanicus*, *M. tumescens*, and *M. leintwardinensis.* A.L. Aymestry Limestone. U.L. Upper Ludlow.

Aymestry Limestone and Lower Ludlow.

The middle part of the Ludlow Series is occupied by beds of limestone which are usually more or less argillaceous, and often nodular. They were named Aymestry Limestone by Murchison, from their excellent development at Aymestry, but they are very variable in thickness, and apparently do not always occur at exactly the same horizon. In fact, as Mr. Lightbody has remarked, "there is a constant intercalation of calcareous beds to the bottom of the Lower Ludlow, of which the Aymestry Limestone is only an exaggeration arising from the casual occurrence of large beds of shells or corals in certain places."

The Lower Ludlow Series is of great interest as containing the last of the Graptolites (see p. 446), and in different localities its fossils vary considerably. Like the other strata of the Ludlow district, it must therefore be examined at many points to obtain a complete idea of the fauna it contains.

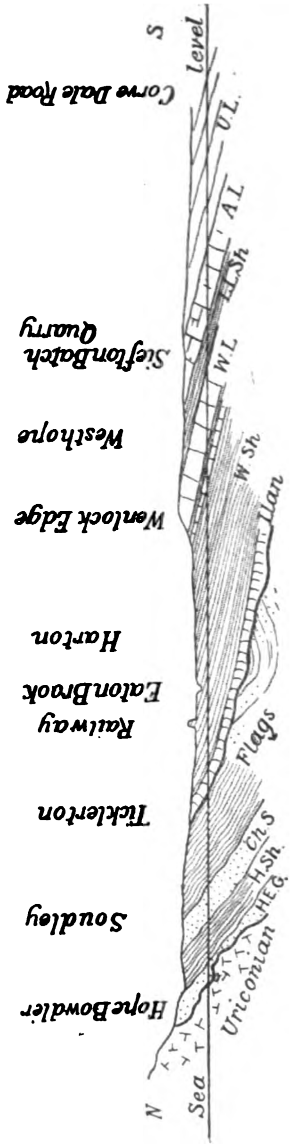

FIG. 32.—SECTION ACROSS SILURIAN AND ORDOVICIAN SYSTEMS BETWEEN CRAVEN ARMS AND CHURCH STRETTON.—*E. S. Cobbold.*

H.E.G. Hoar Edge Grits. H.Sh. Harnage Shale. Ch.S. Chatwall Sandstone. Flags. Longville Flags and Upper Beds. Llan. Llandovery. W.Sh. Wenlock Shale. W.L. Wenlock Limestone. L.L.Sh. Lower Ludlow Shale. A.L. Aymestry Limestone. U.L. Upper Ludlow.

Wenlock and Llandovery Series.

The Middle and Lower Silurian formations have already been

described in the Proceedings of the Association by Professors Lapworth and Watts (1894). The whole series is well seen between Craven Arms and Church Stretton (Fig. 32).

Thanks are due to the Council of the Geological Society for the loan of blocks, Figs. 25—28, 31.

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UNCONFORMITIES IN THE CHURCH STRETTON DISTRICT.

By EDGAR STERLING COBBOLD, F.G.S.

There are five or six well-marked unconformities in the strata of the Church Stretton district, and two of these will be crossed by the Geologists' Association's excursion.

The first unconformity, at the base of the Upper Llandovery, occurs at Ticklerton, but, unfortunately, it is not very well shown in the brook, the actual junction being obscured by surface accumulations. Within a distance, however, of 200 yards we pass from shales with calcareous beds containing *Pentamerus*, to very similar beds containing *Trinucleus* and other common Bala fossils. There is a pretty little anticlinal fold in the *Pentamerus* bed of the brook which serves as a warning that the actual junction may not be so simple as is shown in the section (Fig. 9).

The evidence for the unconformity is obvious from an inspection of the Survey Map. Near the Severn the Llandovery rests directly on the Upper Cambrian shales, south of this it is in contact successively with the various members of the Caradoc series, until at Cardington it rests upon the upper beds. It then passes to Cambrian Shales again, and for a short distance, at the end of the Cardington Hills, to the Uriconian, after which it again rests upon several members of the Caradoc series; and from Ticklerton to the Onny it is upon the highest known member, "The *Trinucleus* Shales."

After escaping from the complicated faulted area near Horderley the Llandovery clings persistently to the Longmyndian; at Norbury, farther west, it is upon the "Upper Longmyndian" (Torridonian?); and beyond this it crosses the disappearing Arenig and Llandeilo ridges of the Shelve area.

The actual junctions are exposed in the Shineton Brook (on Cambrian); at Little Stretton (faulted against Longmyndian); at the Onny (slightly faulted against the *Trinucleus* Shales); at Hill End near Plowden (on the middle member of the Longmyndian).

The second unconformity to be crossed is at the base of the Caradoc Series, the grits and conglomerates of which may be seen at Hope Bowdler actually in contact with the irregular pre-Bala floor of Uriconian rocks, and the fossil-bearing sands contain large subangular blocks of the same rocks.

The two sections here are convincing in themselves, but their evidence is strengthened on following the base northwards, when it is seen to pass from Uriconian to Lower and Upper Cambrian, east of the Caradoc and Lawley Hills. It is remarkable that this unconformity has not been traced west of the line of the Stretton Fault, and that only a few miles off, in the Shelve district, the whole of the Arenig and Llandeilo Series intervene with apparent conformity between the Upper Cambrian and the Bala or Caradoc.

The other unconformities of the district are:

That at the base of the glacial deposits;

An overlapping unconformity beneath the Carboniferous;

The unconformity at the base of the lowest Cambrian;

The somewhat doubtful unconformity between the Upper Longmyndian (Torridonian?) and the Longmyndian proper.

In fact, looking back over the history of the Church Stretton rocks, we see a marked recurrence at many different epochs of marginal conditions of sea and land in the immediate neighbourhood, as well as evidence of repeated earth movements, the last phase of which, the formation of the Stretton Fault, may still be incomplete.

THE BONE-BED IN THE UPPER LUDLOW FORMATION.

By GEORGE J. HINDE, Ph.D., F.R.S.

Of the rocks to be visited during the Long Excursion there is probably none so replete with interest as the well-known Bone-bed in the upper part of the Upper Ludlow Series. It was first discovered by the Rev. T. T. Lewis and Dr. Lloyd, and brought into prominent notice by Murchison's description of it in the "Silurian System." Subsequently* H. E. Strickland records its occurrence at Hagley, four miles north of Hereford; round the north-west margin of the Woolhope district between Stoke Edith and Prior's Frome, also between Lyme Down and Gamage Ford on the south-west side of the Silurian area of Woolhope. It has further been noted at Velt House, near the south extremity of the May Hill elevation, seventeen miles from Hagley, and again at Pynton Passage, forty-five miles distant from its outcrop

* *Quart. Journ. Geol. Soc.*, 1852, vol. ix (1853).

on the banks of the Teme, near Ludlow. R. W. Banks states* that it is present at Bradnor Hill, near Kington, and it has also been found at Linley, in Shropshire.

The Bone-bed is, generally, a single thin layer of rock, sometimes not more than a small fraction of an inch (1 to 3 mm.) in thickness, very seldom does it exceed two inches (50 mm.), but occasionally it reaches to a foot (300 mm.). It is usually of a dark tint, contrasting strongly with the grey or greenish-grey, finely micaceous sandstone between which it is enclosed. It bears locally the name of "Gingerbread"; Murchison remarks that it gives the impression of a triturated heap of black beetles, whilst Dr. Harley compares its appearance with that of linseed oil-cake. On nearer inspection the bed seems to be composed of minute grains of a dark chocolate or mahogany tint, commingled with small shelly fragments of a deep black. The grains are coarser in some portions of the rock than in others, indicating that they have been to some extent sorted by current-action. The rock is nearly entirely composed of organic materials, firmly compressed, and cemented by relatively small amounts of calcite, ferruginous substance, and very fine sandy particles so as to form when unweathered a very compact mass of material; but after surface exposure the rock disintegrates, and the small organic fragments can then be obtained free from matrix. The hard, fresh portions of the rock yield good microscopic sections, but care is required in reducing them to a sufficient degree of transparency.

A piece of the Bone-bed treated with hydrochloric acid is readily attacked, the organic particles are dissolved, and only a small amount of brownish sediment—probably arising from the cementing matrix—remains.

The Bone-bed is composed of the hard, skeletal remains of Fishes, Crustacea, Brachiopoda, and perhaps Annelida. They are now disintegrated and fragmentary, and to some extent rolled and worn. It also contains occasionally the small seed-like plant remains known as *Pachytheca*.

By far the most important of the organic constituents of the bed are the small bony scales, plates, or tubercles forming the skin of Fishes belonging to the placoid division, together with their spines and fragmentary head-shields. They were first described and figured by the late Louis Agassiz, but his determinations have since been considerably modified. Figures of the principal forms are given in Murchison's "Silurian System," and repeated in "Siluria" (Plate XXXV). The commonest of the Fish-remains are the minute scales or tubercles named *Thelodus parvidens*, which occur in myriads throughout the rock, and in some parts mainly compose it. They are smooth, brightly-polished bodies of a mahogany or brownish tint, from .25 to 1 mm.

* *Quart. Journ. Geol. Soc.*, 1856, vol. xii, p. 54.

($\frac{1}{100}$ to $\frac{1}{25}$ inch) in diameter, having the form of an ordinary sleeve-stud, that is of two small plates connected by a narrow neck. The outer or upper plate of the stud is generally smooth and flattened, and either round, oval, oblong, or diamond-shaped in outline, whilst the lower or inner plate has a small cavity, the pulp-cavity, which opens to the surface by a small orifice.

The histological structure of these minute fish-scales is very clearly shown in microscopic sections. It consists of a homogeneous groundmass, kosmin, traversed by closely set, branching tubules, which radiate from the pulp cavity to the exterior of the plate, whilst a thin layer of enamel covers the surface. The scales are now completely detached from their natural positions and heterogeneously commingled in the rock. Additional interest is connected with these scales from the fact that lately some small fishes have been discovered in the Upper Silurian Passage Beds of Lanarkshire with a skin-armour of bony scales closely similar in form and size to those which compose the Ludlow Bone-bed. These fishes have been described by Dr. Traquair and named *Thelodus scoticus*. The detached scales have also been very fully described and illustrated by Rohon.*

The longitudinally ribbed spines or ichthyodorulites named *Onchus Murchisoni*, are generally very fragmentary, and they are less numerous than the scales of *Thelodus*. Their minute structure is less clearly shown than that of these latter bodies and they were regarded by M'Coy as the tail spines of the Crustacean, *Ceratiocaris*. Rohon and V. Zittel consider them to belong to a fish nearly allied to *Thelodus*.

Other fish remains of less frequent occurrence in the Bone-bed are the denticulated cornua of the head-shield of a fish named *Plectrodus* by Agassiz, but now placed by Lankester in the genus *Eukeraspis*. Some fragmentary black plates with concentric ribs or lines have been attributed to *Pteraspis*, but those which I have met with are considered by Dr. Smith Woodward to be portions of the shell of the Brachiopod *Discina*.

Leaving now the undoubted fish-remains, we may consider the small detached bodies to which† Dr. Harley gave the name of *Astacoderma* and referred to the Crustacea. They are very varied in form; some resemble blunted, conical fish-teeth, others the crown of a bicuspid or molar tooth with three elevated and rounded cusps, whilst others are oblong plates, concave below and with a tuberculated upper surface. The minute structure of these bodies, as shown in microscopic sections, consists of delicate lines of growth which are traversed at right angles by thickly-set simple tubuli. In the interior substance of some of the bodies there are minute rounded or oval calcareous corpuscles, which would seem to indicate their crustacean origin.

* *Mem. Acad. Sci. St. Petersburg*, vii ser., Tome 41, No 5.
† *Quart. Journ. Geol. Soc.*, vol. xvii (1861), pp. 542-552, pl. xiii.

Dr. Henry Woodward* has stated that with one exception these forms of *Astacoderma* are founded on the teeth of Phyllopod Crustacea, such as *Ceratiocaris*.

Dr. Harley also states that the Conodonts of Pander possess a similar minute structure to that of *Astacoderma*, but I have failed to find in the former the tubuli which are so prominent in the latter. I have not recognised a single genuine conodont in any portion of the Bone-bed which has come under my notice.

Another group of organic fragments very numerous in the Bone-bed, are bright, lustrous, black semi-cylindrical pieces of shelly bodies, with portions of tubes of similar material, from 3 to 8 mm. in length. These bodies are very conspicuous on the surface of the Bone-bed, and they have given rise to a fancied resemblance to broken up wing-cases of beetles. In microscopic section they only show concentric lines of growth. In general appearance these fragments are not unlike the shelly tubes of *Serpulites longissimus*, Murch., which is of not infrequent occurrence in the Ludlow formation. The evidence seems to me insufficient at present to determine whether they are annelidan tubes or not.

Of the remains of Brachiopods in the Bone-bed, mention has already been made of small black fragments of *Discina*. I have also noted one or two specimens of *Chonetes* and casts of other forms.

Small black coprolitic nodules are frequent. Microscopic sections show that they are mainly composed of the minute siliceous grains of the rock matrix with occasionally a plate of *Thelodus*. It may be doubted if they are due to fishes.

THE GRAPTOLITES OF THE LOWER LUDLOW SHALES.

By ETHEL M. R. WOOD, M.Sc.

The Lower Ludlow Shales, as typically developed in the Ludlow district, constitute in the main an argillaceous group of light mudstones, greenish-brown to grey in colour. They are both underlain and overlain by a limestone series, the Wenlock and Aymestry limestones respectively. Although the Lower Ludlow formation as a whole is well distinguished lithologically from the Aymestry limestone above, yet there is a gradual transition from the one to the other, and the small calcareous flaggy beds which are found in the lower part of the series increase in number and thickness towards the summit, until the Lower Ludlow Shales pass into the typical impure limestone known as the Aymestry. An examination of the palæontological evidence (at least so far as the

* "Siluria," 5th Ed. (1872), p. 542.

graptolites are concerned) brings out the same fact, namely, that there is no great break between the Lower Ludlow Shales and the overlying limestone, and they might be regarded more conveniently therefore as one formation.

The light coloured mudstones of this Ludlow district bear but little resemblance to the black shales of Scotland and Wales, which are so characteristic of graptolitic deposits at other horizons. Graptolites, however, are found in abundance, especially in the softer mudstones and shales, and owing to their manner of preservation, are exceptionally easy of examination and determination.

Although specimens are abundant, yet they are as a whole small in siæe, and at first sight there appears to be but little variety of form. In fact two general types only strike the eye, namely, those that are slender and curved, and those which are fairly stout and straight. The same uniformity is to be found on a closer examination of the individual cells or thecæ. Most of the apertures are either provided with spines, or are quite destitute of ornamentation, and present the simplest type known among graptolites.

A detailed palæontological study, however, reveals the existence of a large number of species and varieties. The differences between these forms are not so striking perhaps as those which are to be found among the graptolites of other formations (such as the Birkhill Shales, for example), but they are none the less constant—nor is it a matter of surprise that such should be the case when we reflect that the graptolites as a whole were approaching extermination in the Lower Ludlow Beds. The characters of most value in the separation of the species and varieties are (1) the form of the proximal end, (2) the form of the polypary, and (3) the shape of the thecæ.

Two genera have been found in the Lower Ludlow Beds of Great Britain, namely, *Monograptus* and *Retiolites*, but of these the former only has been found in the Ludlow district.

The genus *Monograptus* is represented by fifteen well-marked species and thirteen varieties, which fall into the following six groups (only the commonest forms to be found in the Ludlow district are here mentioned):

Group I.—Type *M. dubius*.
M. dubius, *M. tumescens*, *M. tumescens* var. *minor*.
Group II.—Type *M. colonus*.
M. colonus, *M. colonus* var. *compactus*, *M. varians*, *M. varians* var. *pumilus*, *M. Roemeri*.
Group III.—Type *M. chimæra*.
M. chimæra, *M. chimæra* var. *Salweyi*, *M. leintwardinensis*, etc.
Group IV.—Type *M. uncinatus*.
M. uncinatus var. *micropoma*.

Group V.—Type *M. scanicus.*
M. scanicus, etc.
Group VI.—Type *M. Nilssoni.*
M. Nilssoni, *M. bohemicus.*

Of the six groups of *Monograptus* enumerated above, the first two—those of *M. dubius* and *M. colonus*—are by far the most important, and both are rich in species and varieties. The species belonging to these groups, together with those of the two succeeding groups—those of *M. chimæra* and *M. uncinatus*—all bear a close resemblance to one another in the form of the polypary, which is straight for the greater part of its length, but distinctly curved *inward* at the proximal end. They differ from each other, however, in the character of their proximal extremities. and the shape of the thecæ. In the first group—that of *M. dubius*—the thecæ are of the same type throughout the whole polypary and bear simple unornamented apertures, which are at right angles to the general direction of the thecæ. Those of Group II.—that of *M. colonus*—bear two types of thecæ, those of the distal end resembling those of Group I., and those of the proximal end having their apertures ornamented with spines. The structure of their proximal extremities also presents characteristic differences.

The forms belonging to Group III.—that of *M. chimæra*—chiefly differ from those of the preceding group by the presence of spines, more or less stout at *all* the thecal apertures. The separation of this group from that of *M. colonus* must, however, be regarded as provisional, for the presence of thecal spines seems in many forms to be dependent on external conditions, and can hardly be considered of great classificatory value.

Group IV.—that of *M. uncinatus*—is only represented in this Ludlow district by one form, namely, that of *M. uncinatus* var. *micropoma*, and that is a rare fossil.

The two final groups—those of *M. Nilssoni* and *M. scanicus*—are quite distinct from the four preceding ones in the form of the polypary, which is very slender and curved. The species belonging to them, however, differ from each other in the shape of the thecæ; those of the type of *M. scanicus* having a characteristic hooked or claw-shaped aperture, and those of *M. Nilssoni* a simple and unornamented one. Other characters, such as those of the proximal end, also serve to distinguish them.

A comparison between the graptolites of the Lower Ludlow beds and those of the Wenlock below (which may be seen at Burrington and elsewhere in the Ludlow district) reveals some interesting facts. Regarding the graptolite fauna as a whole, it will be seen that the supposed great palæontological break between the Wenlock and Lower Ludlow Beds all but disappears; the same families and genera, and most of the groups of

Monograptus are represented in both. At the same time they differ considerably when we come to study them in detail. Only one or two species are common to both, and it is no difficult matter to recognise at a glance whether we are dealing with a Wenlock or Ludlow fauna.

The main characteristics of the Wenlock graptolites, which serve to distinguish them from those of the Ludlow beds are as follows:

(1) The form of the polypary of many of the Monograptids is straight with a curve *outward* at the proximal end.

(2) The thecal apertures are more frequently curved over into a hook or claw shape, are occasionally simple and unornamented, but never spinose.

(3) Many of the narrow forms give off branches and constitute the genus *Cyrtograptus*.

The commonest graptolites in the Wenlock beds are *M. priodon*, *M. Flemingii*, *M. dubius*, and various species of *Cyrtograptus*.

As we have seen, the Lower Ludlow fauna of graptolites is not an extensive one, nor one of any great variety, the species are never of any great size, and to the collector it bears no comparison with the rich and varied fauna of the Glenkiln, Hartfell, Birkhill, or even Wenlock Shales. Yet it has a special interest of its own to the palæontologist, on account of the fact that here we have the last survivors of that great family of extinct animals, which flourished exceedingly all through the Ordovician and most of the Silurian period, and died out suddenly, leaving hardly a trace behind.

A brief and partial summary of the gradual lines of evolution along which the graptolites appear to have passed, may give an added interest to the study of this small group of survivals. The earliest graptolites, those in the Cambrian and lowest beds of the Ordovician, were much branched forms; many at first with the branches united together along their whole length (*Dictyonema*), and later with the branches free (*Clonograptus*). Gradually the branches became more and more reduced in numbers (*Dichograptus* and *Tetragraptus*) until eventually there were only two left (*Didymograptus*). In all these forms the shape of the thecæ remained practically the same. Development and change now seem to have been centred in the shape of the thecal aperture, and various modifications took place, apparently for the better protection of the polyp living in the theca (*Leptograptus* and *Dicellograptus*, etc.). A further simplification of the polypary resulted in the appearance of a form with only one branch (*Monograptus*). This genus reached its maximum in the Birkhill or Llandovery period, and included a large variety of forms, each characterised by a considerable variation in the form

of the thecal aperture. All the types represented in the Wenlock and Ludlow Beds are merely survivals of similar ones which reached a greater development in these earlier deposits. From the Birkhill period to the Ludlow there is a marked decrease in the number of forms; there is no sign of any new lines of development, and the graptolites were clearly approaching their extermination. There was a revival of branching in the Wenlock beds (*Cyrtograptus*), but this modification of the simple unbranched polypary was of short duration. In the Ludlow Beds, practically only one genus (*Monograptus*) survived, and the species were always small and showed an increasing diminution in size towards the top of the series. The reasons for this fairly rapid extermination of the whole family of graptolites are of great interest, although they cannot be determined with anything approaching to certainty. A possible reason may be found in the change of surroundings. In the earlier formations which were so eminently favourable to their existence, fairly deep and quiet waters prevailed and sedimentation was slow, whereas now these conditions were changing, for the Upper Silurian deposits indicate shallower water. Again, the great development of spines suggests another explanation, for it is possible that this may have been the expression of a necessity for defence against external foes, and it may be remembered that the great class of Fishes was beginning to enter as fresh and powerful competitors in the struggle for existence.

Five main graptolite zones have been detected in the Lower Ludlow Beds of Great Britain, but of these only the four upper ones have hitherto been discovered in the Ludlow district. The zones are:

(1) Zone of *M. leintwardinensis*,
(2) Zone of *M. tumescens*,
(3) Zone of *M. scanicus*,
(4) Zone of *M. Nilssoni*,
(5) Zone of *M. vulgaris*.

The uppermost zone of *M. leintwardinensis*, which is typically developed in this district in the neighbourhood of Leintwardine, includes the Aymestry Limestone and the underlying calcareous laminated flags and light brown mudstones which form the upper part of the Lower Ludlow Shales. *M. leintwardinensis* occurs in this zone practically without associates.

The zone of *M. tumescens* is well seen both along the Elton and Ludlow road, and also in the Elton Lane section, and consists of light flaggy mudstones intermediate in character between the hard flaggy beds above and the softer shales below. *M. tumescens* occurs like *M. leintwardinensis* with few or no associates.

The zones of *M. scanicus* and *M. Nilssoni* may be considered together in this Ludlow district, for they are intimately associated.

The rocks are for the most part thinly bedded mudstones and shales, and are far richer in graptolites than those of any of the other zones. Almost all the typical Ludlow forms are to be found in these beds. They are well exposed in the Elton Lane section, and an abundance of beautifully preserved graptolites may be collected there.

As has been mentioned above, the lowest zone of *M. vulgaris*, which is well developed in the Long Mountain and Builth districts, where the limestone facies is practically absent, has not hitherto been found in the Ludlow district. It is possible that the horizon of this zone is represented by non-graptolitic deposits, perhaps, indeed, by part of the Wenlock limestone. A further examination, however, of other sections where the lowest beds of the Lower Ludlows are better developed will probably reveal the existence of this characteristic graptolite. Hitherto, the graptolite zones have been worked out only in one or two typical sections. Much remains to be done in tracing them throughout the whole extent of country along the great escarpment of Wenlock and Ludlow Beds, which stretches from Much Wenlock to Kington, and still further south.

THE SILURIAN CEPHALOPODA.

By the REV. J. F. BLAKE, M.A., F.G.S.

The Silurian rocks of Britain have yielded about 100 different forms of Cephalopod remains as at present determined; but as farther openings are made in the course of construction of public works the number will doubtless be enlarged, seeing that more than one out of every four of these have been established or modified through the excavations of the South Wales railway at Ledbury. In the growing population of the country the ordinary opportunities of collecting in such rocks are seriously diminished, whence it results that most of the Cephalopods available have been collected long ago, and in such cases the horizon is often unknown or left doubtful. Many also of the specimens on which determinations have to be made are only fragments of parts with some essentials wanting, worn away, pressed out of shape, or concealed so that the identity of two species from different horizons, or even the same from different localities, can only be relied upon as far as it goes, which may not be far.

But after the last twenty years during which time zoning has been invading various parts of the Geological Series, and even *hemeræ* have been attempted, the *identity* of two fossils on different horizons does not seem theoretically possible, though

practically they are indistinguishable, and the prevailing idea is rather to seek the direction in which forms have tended than the fixed points round which they are attached.

From this point of view we have to look to the Ordovician strata to indicate the sources of the Silurian Cephalopods, and to these last to see the origin of those of the Devonian and Carboniferous series. Progress is to be made in this direction by considering not only those forms which may be named as identical species, but also those which are only allied from some point of view.

With these preliminary remarks we can commence with some of those tentative conclusions which further observations may confirm or alter.

With regard to the origin of the Silurian Cephalopod fauna as a whole, it appears that out of 63 forms belonging to the underlying Ordovician only 20 are in any way connected with the 103 from the Silurian, and of these all but three or four have some doubt attached to them, and amongst them all we should probably find only precursors, out of which by mutation the Silurian types have been formed, as an example will show. Thus a specimen from the Bala referred to *Orthoceras annulatum* shows the characteristic festoons but scarcely any ribs. This in the Wenlock develops into having also ribs with either coarse or fine festooning, and in the Ludlow the festoons are represented in *O. fimbriatum*, but it has fine longitudinal risings instead of cross ribs. Thus all three on different horizons have been united by one observer or another, the truth being they really represent mutations. A similar collection may unite *O. angulatum* and *O. bacchus* in the Silurian, with *O. coralliforme* in the Bala beds. Such an association of different forms on distinct horizons in a "reihe," as the Germans name it, is at first very speculative, and requires great caution, but when successfully traced is of great interest, and among all ordinary *Orthocerata* they probably only wait to be understood.

But from the division of this group into two parts, the *brevicones* and *longicones*, we may gather that the former at least may have other successors. The former are few in number in the Ordovician, and scarcely represented in the Silurian. Their place is taken by other forms which by their shape must have had brevicone ancestors. Are these their successors—the *Cyrtocerata*, the *Phragmocerata*, and the *Gomphocerata*? The former of these arise in the Ordovician, but those there found are for the most part *endogastric*, *i e.*, have their siphuncles on the inner or concave side of the partial whorl. Those, however, which occur in the Silurian are not known in this country to have any but *exogastric* siphuncles, the position having changed meanwhile. Next come the *Phragmocerata* with scarcely any Ordovician species, being on the whole Silurian, but their siphuncle is

internal, and their earlier whorls greatly resemble the Cyrtocerata, from the endogastric species of which they doubtless originate. The *Gomphocerata* on the other hand arise later but still in the Silurian, in the upper part of which they are, as a rule, *exogastric*, and may have arisen from that branch of the Cyrtocerata. Their early parts are rare—if found, they should show curved forms.

These last two genera also sometimes assume features, on which we are not at present able to put any interpretation, but only to use them as signs of close relationship. The last septal chamber is often distinguished by a number of festoons in a row, ending downwards but continued in some on the body-chamber for some distance forward, when they die away. Neither these nor the various forms of aperture are shown to have any serious phyletic significance, but as the former affect the last half-sized chamber, they may represent a senile character.

Of wider significance probably is to be the shedding of the septa at the other, or hindmost, end. It is quite characteristic of *Gomphoceras*, showing that their earlier sutures are weak and easily separated, probably a sign of phyletic decay. In other cases there are phenomena connected with the loss of suture, apparently by way of restoration. Thus in *O. truncatum* there is a very convex septum at the end, which runs continuously into the side. This is stated by Barrande to be accompanied by a layer of shell deposited on the truncated end. In *O. Etheridgii* from Scotland there is a remarkable deposit rising round the end septum, coats its extremity and divides into a number of plates more upright than the septum; but this differs by occurring in two or three successive septa, apparently in anticipation of their detachment. More interesting is the occurrence of a number of isolated septal surfaces found in the Upper Ludlow Beds. They seem to have fallen off and to have allowed the inner side of the septum to be exposed. Thus the inside leaves a cast to take a mould of the vascular surface of the mantle which appears to meet round the siphuncle during its earlier stages, and thus leaves an impression of a radiating hollow which passes in various directions, and of the fringed end of the mantle. These are referred to *O. imbricatum* by me, but as they are loose they might easily belong to more than one species if the phenomenon were at all common.

But of all the forms of decay the *Ascoceras* affords the most remarkable instance. The members of this genus found in our Ludlow rocks are all truncated at the base and thus would appear like body chambers till they are opened, when the remarkable sigmoid sutures are seen on one side at considerable distance from each other, coalescing towards the centre and then expanding again to smaller chambers on either side of the wide open siphuncle. But in spite of this, it is still true that *in this*

country "the earlier part is unknown, the body chamber and the last few septal chambers only being preserved in association." In Sweden, however, longer pieces have been found and the earlier part is seen to have the form of a long narrow *Orthoceras* with remote septa. This shows completely that an Ascoceras is the senile stage of an Orthoceras (somewhat of the build of *O. distans*) in which the last chamber has been retarded on one side. To complete the story separated portions of *the earlier part* should, now that they are recognisable, be sought in the Upper Ludlow rocks.

Other questions, specially relative to the rarer forms, still call for solution, but they can only be mentioned. There is the genus *Actinoceras* (not founded only on the presence of the organic deposit in a swollen siphuncle, but on structures within it), which is widely spread in the Silurian rocks, but is represented only by its series of siphuncles with a few septa embedded in the rock. No names beyond general ones can therefore be given to such forms and very little progress made with them.

In the other direction are the rare group of *spirales*. The first to appear is the *Trochoceras* of unsymmetrical form, but there is nothing in the position of the siphuncle or otherwise to distinguish Ordovician from Silurian forms in general, nor anything to indicate their origin, though they are much more numerous in the Silurian. Amongst the so-called *Nautili* and the *Lituites* there is so much range of form and so few points of connection that we are quite at sea as to their origin and can only conclude that they are at the period considered very far from their origin, or that their development was very rapid in those early days.

SOME LUDLOWIAN BRACHIOPODS: AND A QUESTION ABOUT SILURIAN TIME.

By S. S. BUCKMAN, F.G.S.

So many pitfalls beset the arm-chair palæontologist, and so often does he fall into them, that I hold as an article of faith the necessity for a course of field-geology as a stage in the ontogeny of palæontologists—especially of those who study the invertebrates. First catch your fossils in the field, should be their motto; to learn them geologically before describing them is most important. To paraphrase Burns, this course

"Should frae mony a blunder free us, and foolish notion."

Nor ought the geological work to be confined merely to the neanic stage of the palæontologist. After he has arrived at full

vigour he should have the opportunity to devote one or two months a year to study in the field the particular group of organisms which may be claiming his attention at the time.

Holding these opinions I confess myself imperfectly equipped for the task of saying anything concerning the Brachiopods of the Ludlowian. For it is only from the arm-chair point of view that I am acquainted with them. Yet the necessities of environment sometimes compel an acceleration of development direct from the brephic into the ephebic stage, and such tachygenesis is imperative in this case, if any fruit is to be yielded; but the quality of such fruit is necessarily imperfect.

Some of the principal species of Brachiopods, which text-books ascribe to the Ludlow Series I set forth in the annexed table, putting in brackets the modern names.

Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.
Lingula lata	Strophomena filosa	Chonetes lata
Pentamerus galeatus	[= Stropheodonta]	,, striatella
[= Sieberella galeata]*	Stroph. depressa	Rhynch. nucula
Discina rugata	[= Leptæna rhomb-	,, Wilsoni
[= Orbiculoidea]	oidalis]	[= Wilsonia Wilsoni]
Atrypa reticularis	Stroph. euglypha	Discina rugata
	[= Strophonella	[= Orbiculoidea]
	euglypha]	Orthis lunata
	Rhynchonella nucula	? [= Dalmanella]
	Rhynch. Wilsoni	Orthis elegantula
	[= Wilsonia Wilsoni]	[= Dalmanella
	Rhynch. navicula	elegantula]
	[= Dayia navicula]	
	Lingula Lewisi	
	,, striata	
	Pentamerus Knighti	
	[= Conchidium	
	Knighti]	
	P. galeatus	
	[= Sieberella galeata]	
	Atrypa reticularis	

* Assigned to genus *Gypidula* by Schuchert.

Of the species here mentioned the one most likely to attract attention is the fine *Conchidium Knighti* of the Aymestry Limestone. Davidson only admitted this one form to specific rank, but there is another form to which Sowerby gave the trivial name *Aylesfordi*. This is the broad, flabellate form whose general appearance is certainly very distinct from the narrow, gibbous *C. Knighti*. The *C. Aylesfordi* really takes us a step further back towards the common Pentamerid ancestor, and one can hardly doubt that the true relationship of the two forms is this—*C. Knighti* developed out of *C. Aylesfordi*.

The geographical distribution of Brachiopods is an interesting subject, important especially for any palæogeographic reconstruction theories. Schuchert (1) has well remarked: "When

paleontology shall have advanced sufficiently, so that extra-continental correlation of Paleozoic formations can be taken up in detail, it will be seen that Brachiopods, because of their wide dispersion, abundance, and favourable preservation, will be of great service in working out paths of migration and intercommunicating oceanic basins" (p. 17). Now the geographic distribution of so striking a genus as *Conchidium* may reasonably claim our attention for a minute. Schuchert (1) lists twenty species of this genus for America, of which eighteen are found in the Silurian, and two in the Devonian. Of the eighteen Silurian species the majority are found in the Niagara series, which is, according to Schuchert, Meso-Silurian—say, Wenlockian, and that is where Geikie places it (2, p. 775). In the British Museum (Nat. Hist.) collection there are specimens of *Conchidium* from the Silurian of the Arctic regions. Eastward of England we find the genus in Gotland, in Russia, and in Siberia. There are specimens from these places in the Natural History Museum Collection, and the fine *C. tenuistriatum* from the Wenlock of Gotland is particularly interesting as taking us still nearer to the Pentamerid ancestor than does *C. Aylesfordi*, so that its biologic and geologic positions seem in exact accord. I saw no species of *Conchidium* from the Silurian of Bohemia in the British Museum. Davidson (3) does say that *C. Knighti* occurs there, but I fancy the statement requires confirmation. Excluding the Bohemian record we find a curiously wide east and west dispersion of *Conchidium* and a very limited north to south range. In Europe it seems confined to a district north of a line coinciding with an extension of the Mendip axis, as if that formed, in Silurian times, an important barrier. Then, again, the genus is not recorded from the Silurian of Scotland.

One investigation then may be suggested to those who are concerned with the Ludlow rocks—how was the sea of the Ludlow area connected with those of the other areas where *Conchidium* is found?

But do the visitors require something more immediately concerned with field work? Then I suggest that they search for specimens showing internal characters. These are all-important for modern classification. What, for instance, are they in the case of *Rhynchonella nucula*? The whole of the Rhynchonellidæ are now under consideration for generic revision according to their internal characters; and accurate information about each species is required.

Or the visitors may try to verify some of the records given in the Table. To a Mesozoic geologist, accustomed to find forms so very limited in their vertical ranges, some of these records look suspicious. Such records in Mesozoic rocks have generally turned out to be due to incorrect stratigraphy, or to inaccurate palæontology, and most trouble in the latter case has arisen through the

phenomena of homœomorphy. Are there no cases of undiscovered homœomorphy, and no incorrect identifications among the British Ludlowian Brachiopods? If not, they are in a happy state as compared with the Mesozoic. But as the Scotchman said, "I hae ma doots!"

My Mesozoic experience has made me very sceptical. I want confirmation in many cases. For instance *Dalmanella elegantula* is a Wenlockian species; and it is even credited to the Ordovician; and it is interesting as being found in the Clinton and Niagara beds of America. Is the quotation from Upper Ludlow correct? I have seen specimens of *Dalm. elegantula* and *Rhipidomella hybrida* mixed on the same exhibited tablet though the valves showing interior characters had also been carefully displayed. Again *Sieberella galeata* is a species of the Wenlockian, but it is said to occur also in the Lower Ludlow and the Aymestry beds. But in the British Museum the only evidence in support that I saw was two fragments from the Ludlow beds, doubtfully *Sieberella*, still more dubiously *S. galeata*. Schuchert (1) tells us that this species occurs in the Eo- and Meso-Devonian of America. Are the English and American identifications of the Gotland species both correct? If so it is a strange contrast to our present experience of range of Brachiopod species in Mesozoic rocks.

I must take this opportunity to congratulate the Americans on the high pitch of perfection to which they have carried their studies of Palæozoic Brachiopods, and the excellent work which they are accomplishing in palæontology generally. Especially commendable is the manner in which they are systematizing knowledge. Palæontological dictionaries like Schuchert's Index of Brachiopods are an immense boon. Like Oliver Twist we cry for more. On this side we can be justly proud of Sherborn's monumental work; such books should help and encourage palæontologists to go and do likewise in their special lines.

The range of Brachiopod species suggests a question about the Silurian strata. What is their chronometric value (a) as regards actual time; (b) as regards species-life; (c) as compared with Mesozoic rocks? Taking the last portion of the question first: Is the Silurian, divided into Llandoverian, Wenlockian, Ludlowian, to be compared with, say, Lower Oolites divided into Aalenian, Bajocian, Bathonian? If it be said, as is generally assumed, that the time taken to deposit the former was so much greater than that taken for the latter, then it would have to be conceded that the length of what may be called species-life in the case of Brachiopods is greater in Silurian times than in Mesozoic. For to me it seems that the length of species-life is from $\frac{1}{3}$ to $\frac{2}{3}$ the whole of Silurian time, but from $\frac{1}{15}$ to $\frac{1}{20}$ the whole of Lower Oolite time. Is the difference due to difference in palæontological methods? to inaccurate records? or did sediment accumulate faster in

x amount of Palæozoic than in x amount of Mesozoic time? or did Brachiopod species exist a much shorter time in Mesozoic than in Palæozoic days? If species lived as long in the one time as in the other we should be driven to the conclusion that the Silurian strata were actually deposited in a much shorter time than the Lower Oolites. This sounds extremely heterodox, yet when we consider the many penecontemporaneous erosions now indicated in Lower Oolite times, and the very limited vertical range of Brachiopod species which is so great a contrast to what seems to obtain in the Silurian strata, we shall be forced to conclude that the Lower Oolite rocks may represent a vastly greater amount of time than their mere thickness appears to suggest. So I present this heterodox idea to the members of the Geologists' Association, hoping that, in it and in the other remarks, they may find subjects for consideration when they visit the classic Ludlowian strata.

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THE SILURIAN PLANTS.

By E. A. NEWELL ARBER, M.A., F.G.S.

It is now generally admitted that the earliest known fossils which can be referred with certainty to plants, occur in the Silurian rocks. From theoretical considerations, it is also evident that a very varied flora must have existed in the Silurian period, and this would probably be discovered if deposits formed in the estuaries or freshwaters of the time could be examined. Hitherto, however, none but the most unsatisfactory remains have been obtained, and the ancestors of the rich floras of the Upper Devonian and Carboniferous periods have still to be revealed. The common impression that seaweeds predominated in the Silurian flora is probably false, and due merely to the scantiness of the geological record; and many of the fossils which have been referred to Algæ are too obscure for definite determination.

The genera *Nematophycus* and *Pachytheca** are true British plant-remains of Silurian age about which there is general agreement as to their nature, although their affinities are still obscure. Curiously enough both these fossils occur as petrifactions.

* A full description of these genera and the literature on the subject will be found in Seward's *Fossil Plants*, vol. I, 1898, pp. 192-204.

Nematophycus consists of silicified trunks, which in Canadian specimens have been found more than two feet in diameter. The British specimens, of smaller size, have been found in beds of Wenlock age at Cardiff, and also at Corwen and elsewhere in North Wales. The stems are usually formed of a number of fairly large loosely arranged vertical tubes, between which are a number of smaller tubes ramifying in different directions. In some species, rings of growth are seen, which recall the annular rings seen in the trunk of a forest Dicotyledonous tree.

Nematophycus is known from the Silurian and Devonian rocks of Canada, the Silurian of Britain and the Devonian of Germany. The affinities of this plant are still obscure. Dawson, who first described the genus under the name *Prototaxites*, regarded it as a Conifer allied to the Yew. Carruthers however proposed the name *Nematophycus* on the grounds that these stems more closely resembled in structure certain large Antarctic algæ such as *Lessonia*, and concluded that in all probability Dawson's plant was a "colossal fossil seaweed."

Associated with *Nematophycus*, small spherical bodies, of about half a centimetre in diameter, are occasionally found. Sir Joseph Hooker suggested the name of *Pachytheca* in 1853 for such bodies occurring in the Ludlow Bone-bed. A section of one of these small spheres shows an outer tissue of radially disposed tubes, surrounding an inner plexus of ramifying narrow tubes.

The nature of this fossil is still entirely a matter of conjecture. Dawson thought that it was the seed of his *Prototaxites*. Others have regarded *Pachytheca* as probably of an algal nature. It is, perhaps, best and safest to speak of it as a plant of doubtful affinity.

The fossils known as *Psilophyton* which occur in the Old Red Sandstone of Britain, are generally regarded as more closely allied to the Lycopods than to any other group. *Psilophyton* consists of a more or less horizontal stem or rhizome, from which spring erect, dichotomously forked branches, covered with small spiny protuberances which are regarded as probably of the nature of leaves. The branches at the apex are rolled up in a crosier-like manner, as in many recent ferns.

The fructification is, however, little known, and until this has been made out in detail, the precise affinities of *Psilophyton* must remain open to doubt.

The genus *Arthrostigma*,* occurring like *Psilophyton* in both Britain and Canada, is a similar fossil differing in certain details from the latter genus, but probably of kindred affinity. Others of the same type have been described, a type which is undoubtedly characteristic of the flora of Lower Devonian, whatever may be the real affinities of the group.

* See Kidston, *Proc. Roy. Phy. Soc., Edinb.*, vol. xii, p. 102.

NOTES ON THE IGNEOUS INTRUSIONS OF STANNER ROCKS AND HANTER HILL.

By FRANK RAW, B.Sc., F.G.S.

To the south and east of the Archæan ridge of Old Radnor there runs another ridge rising very abruptly from the intervening lower ground. It runs from N.E. to S.W., roughly parallel with the axis of Old Radnor Hill, and attains even greater altitude. It is divided into three hills, of which Stanner Rocks, the northernmost, reaches 1,150 ft., Worsel Wood, the middle one, 930 ft., while Hanter Hill to the south, by far the most imposing, even reaches 1,360 ft.

Like Old Radnor Hill they owe their elevation to the fact that their rocks are of so much greater hardness than the soft Lower Ludlow shales which for the most part surround them. They are bosses of igneous rock, mostly gabbro and coarse dolerite, but containing also many other types. Their continuity is broken at Stanner Station by the low valley (about 570 O.D.) through which the river, railway, and road pass. This valley is probably the site of a considerable fault. The second break is between Worsel Wood and Hanter Hill, where an old valley crosses, the pass being a little over 700 ft. The hills extend in a direction parallel with the great fold and fault lines which have affected the district, and they are found to occupy an anticline, while they seem to be largely bounded on both sides by faults. They probably form a great laccolite, which perhaps owed its existence to the difference in character between the yielding shales which underlie it and the strong rock above which now forms the escarpment of Hergest Ridge and Bradnor Hill to the east. The resistance afforded by the Archæan massif to the west, of which Old Radnor Hill is the topmost remaining part, probably determined the exact position, as, when thrust against this massif the shales crumpled up, but the hard rock was bent, while the basic igneous magma was squeezed in between. The hard cover has gone, but the crumpled shales can be traced at the north end of Stanner in Navages Wood, where they are about vertical, and past the south end of Hanter where they dip at high angles. Again between Hanter and Worsel Wood on the east side the valley seems to be in the Silurian under the laccolite. Folds of the burnt shale beneath come up through the basalt of Worsel Wood, while along the west side of Hanter Hill, where the igneous rock is not bounded by a fault, the burnt Silurian shale can be traced up to it. To the west of this is a part of the laccolite detached by a N.E. and S.W. fault.

The igneous rocks are exceedingly variable, but the great

majority are basic ranging from glassy basalt to very coarse gabbro with crystals up to three inches in length. There is more than one large intrusion, and these are traversed by numerous dykes of finer, and often of more acid, material, especially andesites, felspar-rock, granophyre, and micrognanite. Hanter Hill will perhaps serve as a rough index of the scale of the intrusion: the coarsest gabbros are on the top, which is probably not less than 400 feet above the Silurian floor, and as there would probably not be less rock above than below the coarsest crystallization this gives us 800 feet as an approximate thickness of the intrusion. Among the fine dolerites are some which strongly suggest that of the Clee Hills. The different intrusions not improbably belong to one period, possibly covering that of the Clee Hills, which latter cannot be earlier than Coal Measure time, moreover they are certainly of the same age as the great folding, a consideration which also indicates late Coal Measure or Permian. It is not impossible that the magma had active vents at the surface, and if of late Coal Measure time such vents might have ejected some of the fragmentary volcanic material so abundant in the Midland Coalfields. Numerous dykes of igneous rocks, mostly dolerites and andesites, also cut the Longmyndian of Old Radnor, some of which are apparently identical with these.

A few notes on the chief rock types may be added. The most readily accessible are at Stanner, close to the railway station. Of these a description has been given by Professor G. A. J. Cole (see Bibliography, p. 13, 1886). The dominant rock is a fairly coarse gabbro, which is cut by veins of dolerite, andesite, and white felspar rock, which in some specimens closely resembles quartzite. Under the microscope the gabbro is peculiar in containing both diallage and hornblende; some specimens having, indeed, a rhombic pyroxene as well. The hornblende and diallage are remarkably intergrown, forming two interpenetrant sponge-like masses, while diallage crystals are surrounded by hornblende. The latter growth of hornblende is perhaps secondary, but where so intimately intergrown it would seem that the two were crystallising simultaneously. This sponge-like intergrowth of minerals is a frequent character, being the general relation between the felspar and diallage over a large area on Hanter. On the top of Stanner Rocks are considerable intrusions of the white felspar rock passing into granophyre, the latter containing microcline and quartz, and showing micropegmatitic texture. Veins of the same character occur in Worsel Wood and on Hanter, where, especially in the north-east, microgranite is found. Worsel Wood shows for the most part fine dolerite and basalt, probably the bottom only of the laccolite being left. On Hanter is the greatest variety of Rock types. There is every gradation from exceedingly coarse gabbro to the finest basalt. The gabbro occupies the top and east of the hill, and

graduates downwards through coarse ophitic to fine ophitic dolerite. It is exceedingly variable both in grain and texture, some parts have diallage crystals two or three inches in length, some of these showing very perfectly the paramorphic change into green hornblende. Sometimes the diallage, sometimes the felspar is idiomorphic, but perhaps the dominant type is that already mentioned, in which the felspar and diallage crystals form mutually penetrant sponge-like masses, thus giving "lustre-mottling" on a large scale.

An orthoclase-bearing variety is also very striking, large pink orthoclase crystals being about as abundant as the white plagioclase. The lower slopes of Hanter Hill are formed of finer-grained rocks, especially at the north and south ends.

EXCURSION TO CUXTON.

JUNE 4TH, 1904.

Director: F. J. BENNETT, F.G.S.

Excursion Secretary: HAROLD WALKER, A.R.C.Sc., F.G.S.

(*Report by* THE DIRECTOR.)

OWING to its being a whole-day Excursion and also, perhaps, to the fact that all the sections to be seen were in Drift—with few, if any, fossils—only a small contingent turned up under the charge of the Excursion Secretary, Mr. Walker. They were met at the station by the Director and Canon Toone, the rector of Cuxton, who most kindly accompanied them part of the time, pointing out matters of interest, and who had also proffered refreshment, for which time did not permit.

While waiting for the train, the Director had learnt from the station-master, that a skeleton had recently been dug up on Cuxton Hill close to the church, and that he was so much struck by its likeness to the cave type of skull—a nearly perfect one—that he made a sketch of it, which he gave to the secretary. The bones, under a coroner's order, had been placed in a box and buried in the churchyard. This seems rather unfortunate in the interests of science.

The Director then showed them the chalky drift, with some flints and sarsens banked up against the extremity of the eastern spur, which, with that facing it from the north, seemed to him may at one time have been united and have shut in the valley, forming the basin of a lake to the west of Cuxton.

The party then proceeded to view a section of brickearth on the eastern side of a ridge within these spurs, which, at least, was evidence of still water in that direction. The Director also pointed out in the section some chalky drifts within the brick-earth, a fine buff loam with a few flints, and thought that the brickearth might be due to the decalcification of this chalky drift.

Coming to the other side of this ridge, to a spot whence a view could be obtained up the Cuxton valley, the Director said a few words on the possible formation of such a dry-chalk valley.

The Geological Survey, he said, had usually mapped these valleys, excepting the mappable gravel near their mouths, as bare of Drift; but a little consideration would soon show that, with such a widely-branching and deep-cut valley as this, which must once have contained water, so much material cannot have been removed without leaving some remains in the higher parts of it; and so in the drift map he was now making for himself he had mapped Drift right up to the heads of all the branches of the contributory valleys.

He also stated that the well-marked, and, perhaps, once-

conjoined spurs just mentioned, showed at the mouth of the valley what was only a closing episode of what must have occurred all the way along it, and that higher up he could, he thought, see other spurs that had once been connected and had held lakes. He pointed out, also, that within these spurs there was a distinct flattening of the valley bottom caused by the Drifts that concealed the true bottom. This flattening he had noticed quite high up the heads of the upper reaches of the valley in question, and it was common, he considered, to all these dry-chalk valleys.

He considered that in its initial stage this valley, or the site of it, might have been occupied by small lakes, Bourne-lakes he might term them, such as those he had seen at Croxton Heath, near Thetford, Norfolk, a chalk area thinly covered by Glacial Drift, and mapped by him. These lakes rose and fell with the rainfall; one of them was of a remarkable shape, and was called Punch-bowl Mere, and was a deep cylindrical hollow perhaps 60 feet deep, and 100 or more across.

Mr. Dibley said a few words about the variations in the level of the zones in the chalk, pointing to an anticline, and the Director then quoted what Prof. Hughes had said in the *Geological Survey Memoir*, vol. iv, about this anticline on p. 350. He says, "The chalk on the western side of the Medway dips to the N.W., and that on the eastern side to the N.E., therefore, the river runs along an anticlinal axis parallel to the general northerly dip. East of Wouldham and south of Borstal a north-easterly dip can be clearly made out, while west of Wrexham and in the large pit in the front of the 'Coach and Horses' below Frindsbury, the beds may be seen dipping to the north-north-west, and in the quarry at Whorn's Place may be seen dipping north-north-west, though this is not very clear."

The party then crossed the valley, when Canon Toone pointed out the evidences of the vast amount of gravel that had been removed from the bottom of it by a London contractor. The hill above the church was then visited, capped, as pointed out by the Director, with Southern Drift. In this Dr. Salter recognised a piece of sandstone from the Hastings Bed. Passing through the churchyard some very ancient and rudely incised faces on some old tombstones were pointed out by the Director, who had been making sketches of these from various churchyards in Kent. His sketches were shown and much interested the party, and he stated that so overgrown were these stones by lichen that until that was rubbed away nothing could be seen. The Director also pointed out the old pre-historic cultivation terraces so well seen in the churchyard and rectory grounds. There also the Rector showed where traces of Roman foundation had been found, and exhibited the fine palæolithic implements found quite recently by the Director in his presence

in the bank of the Rectory drive, from the spot where all those fine ones now in the Rochester Museum were found by Mr. G. Payne, F.S.A.

The party then took leave of Canon Toone, thanking him for his courtesy and offer of refreshments; the party then examined the chalk rubble drift in the road cutting by the church, mixed with much sand and loamy in places.

Whorn's Place was then passed, and the Director read a few notes kindly drawn up for him by Miss Sibley, late schoolmistress, and still parish clerk of Cuxton, stating that it was called so after Sir W. Whorne, Lord Mayor of London, 1487.

Nothing now remains except the fine red-brick barn said to be the largest tythe barn in Kent, excepting, perhaps, that of Boxley. The old house was removed when the railway was made.

Lunch was eaten close to Whorn's Place in Bore Hole Quarry, and after this the chalky drift on the hill slope by the quarry was examined, with a few land shells of which three varieties were found.

After a walk along the Pilgrims' Road, a footpath was taken across the valley bottom to Lower Halling.

The Director remarked on the flatness of this valley bottom as evidence of drift, and full proof of this was then seen at almost the lowest part of the valley in the deep tramway cutting, which most unexpectedly showed nearly 40 feet of fine chalky drift, termed "Scarp" Drift by the Director, with occasional lenticular beds of flints and of buff loam. The passage of this fine chalky drift into loam was once shown in a small pit near the railway and the river, but now closed.

The well-marked detached hill between Upper and Lower Halling, at the base of which is the cutting in question, was stated by the Director to be also capped with Southern Drift like the one near Cuxton Church. He then made some remarks on the thinning of beds by vertical dissolution producing local "Residual Drift" that had not been transported, and the thinness of the two patches on the hill tops in question, and indeed of much of the Drift within the Weald, was referred to this vertical dissolution, a conclusion with which Dr. Salter was inclined to agree.

The Director then explained what he meant by the term "Scarp Drift," and "Residual Drift," so well seen in the cutting, and at School Farm pit, and in the sand pit by Peters' works.

He stated that since his residence, now for over four years, in Kent since retiring from the Survey, he has been naturally much impressed with the vast amount of the waste suffered by the wearing back of the Chalk escarpment, and thought that some of this must surely be still to be seen. Also this waste must largely consist of chalky matter, as the Chalk with Flints was very

thin on the crest of the scarp, compared to the middle or lower, with few or no flints. At the base of the scarp he noticed distinct flats or terraces, and that these were covered with a pellety chalk. He then began mapping these terraces showing this pellety chalk. After a time he found full confirmation of the existence of this chalky Scarp Drift in the tram cuttings along those chalky flats, of which the one they had seen was a very good example.

Halling Churchyard was visited, and examples of these old, quaint tombstones seen. The oldest he had yet seen bore the date of 1679, and was most archaic. The very few older than this were quite plain.

The ferry then was taken, and the Scarp Drift at School Farm pit was visited, and after that a shallow one by Peters' works. There was found a small section of the Southern Drift beneath Chalky drift, in which Hastings Sandstone again was found.

Then the deep "sand hole" by Peters' works was visited, by kind permission of Mr. Peters, who had also placed ladders to help to explore this hole.

Some of the more adventurous followed the Director down these ladders, and saw the 18 feet of Chalky Drift, with many large, unworn flints, a few brown ones at the top, all so intermixed with sand as to be dug and sifted merely to obtain this. Below was seen the fine sand, devoid of any chalky drift, but as to what this sand might be no one ventured an opinion, in the absence of any fossils.

In the chalky drift above, numerous mammoth remains have been found, among them a tusk 14 feet long.

The river was then crossed by ferry, and an early train taken to Aylesford, and a much needed tea obtained at "The George."

Much refreshed after this, the party visited Mr. Wagon's great gravel pit. All they saw there much impressed and interested them. This pit has been visited on former occasions.

The only new evidence was that afforded by the Director, who pointed out a thin capping of chalky Scarp Drift over the Southern Drift, thus showing two distinct drifts there of different origin.

This Scarp Drift thickens to the north to some 18 feet, as shown in the recent sewage sections at Aylesford.

The excursion then terminated with the usual vote of thanks to the Director, which was acknowledged by him.

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EXCURSION TO HASTINGS.

JUNE 11TH, 1904.

Director: W. J. LEWIS ABBOTT, F.G.S., F.A.I.

Excursion Secretary: HAROLD WALKER, A.R.C.Sc., F.G.S.

(*Report by* THE DIRECTOR.)

THE party journeyed to Hastings, and were met at Warrior Square by Mr. Lewis Abbott and some members who had travelled by other routes. After alighting at Hastings Station they proceeded to the Town Hall, where, in the unavoidable absence of the Mayor, they were welcomed to the town by Mr. Alderman Tuppenny in a genial speech, to which the President responded. After partaking of refreshments, kindly provided by Mr. Tuppenny, the party was joined by a number of the members of the Corporation and with the influential people of the ancient town, numbering in all between 70 and 80, proceeded to the West Hill, adjoining the Castle. Here a general account of the origin and denudation of the Wealden area from secondary to historic times was given by the Director. The Hastings kitchen middens were then visited and explained. The end of one of these old refuse accumulations still remained untouched and was opened up by the Director. Here was seen one of the old hearths with a layer of charcoal some three inches thick resting upon the baked hearth beneath, with bones, shells, and worked and burnt flints. The cliff at this place is over 200 feet high, and at about three-fourths of the way up there is a ledge some 30 yards wide. The rocks weather into minor ledges and are very much fissured, leaving openings up to ten or twelve feet wide for many yards in extent.

It was claimed that these were by far the most important and complete set of relics that had ever been unearthed in one place, furnishing us with a list of the animals of the period, the mollusca and fish upon which these people fed, their implements, which for minuteness of size, quaintness of outline, and delicacy of working were quite unique; their pottery and other relics of a civilisation, which was said to resemble in many respects that of the Terra del Fuegans of to-day.

The ancient castle was next visited under the able direction of Mr. Chas. Dawson, F.G.S., F.S.A., and Mr. John Lewis, C.E., F.S.A., by the kind permission of the Earl of Chichester, and the history of this ancient pile and its many interesting features were explained in a manner which no one else could do. Details were also given of the excavations which brought the different parts of the building to light, with which these gentlemen

ORDINARY MEETING.

FRIDAY, JULY 1ST, 1904.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association: W. Henry Barnes, P. de B. Benson, Dr. Max M. Bernstein, Prof. W. Boyd Dawkins, M.A., D.Sc., F.R.S., Isaac Hodges, Henry Alfred Hubbersty, Herbert Smith.

The President then delivered a lecture on "The Geology and Fossils of the Ludlow District," with special reference to the Long Excursion, his remarks being illustrated by specimens and lantern slides.

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INDEX TO VOL. XVIII.

NOTE.—The enclosure of a page-number in square brackets signifies that upon that page the paper or lecture is not printed IN EXTENSO, *but is merely announced or otherwise referred to.*

SPECIAL ATTENTION IS DIRECTED TO THE INDEX TO ROWE AND SHERBORN'S PAPERS ON THE "ZONES OF THE WHITE CHALK OF THE ENGLISH COAST," PARTS I, II, III, AND IV, TO BE FOUND ON PP. 373–394 OF THIS VOLUME.

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